MASTER'S THESIS
IND590

MAPPING OF **STRATEGIC FACTORS** FOR **2ND LIFE BATTERY REPURPOSING**

A QUALITATIVE MULTIPLE CASE STUDY OF NORWEGIAN ACTORS

AUTHORS

KIELLAND, KASPAR

SKIBSTAD, KRISTIAN ØREN

SUPERVISORS

HELLSTRÖM, MAGNUS

O'BORN, REYN

DATE

MAY 20, 2022

UNIVERSITY OF AGDER

FACULTY OF ENGINEERING AND SCIENCE

SCHOOL OF BUSINESS AND LAW

ACKNOWLEDGMENT

This paper constitutes our master's thesis in the study of Industrial Economics and Technology Management taught at the Faculty of Engineering and Science and the School of Business and Law at the University of Agder, Campus Grimstad. Over the last four semesters, this master of science program has given us insight into how to analyze, develop, and manage projects. In addition, we have also gained an understanding and knowledge of innovation processes and technology-oriented business areas. In combination with our background from a bachelor of engineering, these areas have been contributing factors when selecting a topic for this master thesis.

We focused our thesis on the Norwegian market for second-life battery applications. This focus came from our collective understanding that this is a topic of great relevance in the green shift. Furthermore, through research in a market of sustainable products, we believe that this study can contribute to society by highlighting factors of interest for businesses to enter the second-life battery market.

We want to thank all informants for taking their time to participate in this research: Without your knowledge, experience, and insight, this would be an incomplete product.

At last, we would like to express our deepest gratitude to our supervisors, Magnus Hellström and Reyn O'Born; your supervision during this semester has been invaluable.
Thank you!

Kaspar Kielland
Grimstad, Norway
May 20, 2022

Kristian Øren Skibstad
Grimstad, Norway
May 20, 2022

SUMMARY

Policies for energy efficiency and renewable energies, as well as consolidating CO_2 standards for vehicles, have been implemented to achieve climate targets set by The Paris Climate Agreement. In recent years these actions have led to a boost in the global electrification of the transport sector, and hence Electric Vehicles (EVs). In Norway, EVs represented a market share at 55% in 2020, making the country a first-mover internationally.

A Lithium-Ion Batteries (LIB) is removed from the EV when the retaining capacity drops below 80%, which will lead to an increase of decommissioned LIBs in the future. In recent years, the amount of End of Life (EoL) batteries has been seen as a business opportunity, giving rise to several start-ups employing decommissioned EV batteries in second-life applications.

This thesis aims to cover a gap in the research literature, focusing on contributing valuable insight with empirical data from the Norwegian repurpose market. Through a qualitative multi-case study design, a selection of established businesses, either directly or indirectly connected to the Norwegian repurpose market, were studied.

Findings mapped out strategic factors for repurposers and identified barriers and drivers in the Norwegian repurposing market. The use case of second-life batteries, channels for sourcing second-life batteries, and how the different cases can overcome barriers in the market proved to be the most influential factors. Barriers within the second-life battery market occur due to a lack of market structure and national regulatory standards. Moreover, empirical evidence shows a need for governmental facilitation to expand the market for second-life battery repurposing.

Keywords: Lithium-Ion Batteries; Second-life battery; Repurposing; Strategic factors; Regulatory standards.

SAMMENDRAG

Nye retningslinjer for energieffektivitet og fornybar energi, samt konsolidering av CO_2 standard for kjøretøy, har blitt implementert for nå klimamålene satt av Parisavstalen. De siste årene har disse handlingene ført til et løft i den globale elektrifiseringen av transportsektoren, og dermed og salg av elbiler (EVs). I Norge representerte EVs en markedsandel på 55% i 2020, noe som gjør landet til en internasjonal pådriver.

Et Litium-Ion Batteri (LIB) fjernes fra en EV når den gjenværende energilagringskapasiteten faller under 80%. Dette vil i de kommende årene føre til en drastisk økning i antall brukte EV-batterier. Den økte mengden tilgjengelige brukte EV-batterier har de siste årene blitt sett på som en mulighet for forretning, og har gitt opphav til flere oppstartsbedrifter som bruker disse batteriene i energilagrings-applikasjoner.

Denne masteroppgaven har som mål å dekke mangler i forskningslitteraturen, ved å bidra med verdifull innsikt og empiri fra det norske markedet for gjenbruk av EV-batterier. Et selektert utvalg av etablerte virksomheter, med direkte eller indirekte tilknytning til markedet, ble studert ved å anvende et kvalitativt multicase-studie.

Funnene kartlagte hvilke strategisk faktorer som er mest kritiske, og identifiser barrierer og drivere i det norske markedet for gjenbruk av EV-batterier. Anvendelse av brukte EV-batterier, innkjøpskanal av brukte EV-batterier, og hvordan virksomheten overvinner barrierer i markedet, viste seg å være de mest kritiske faktorene. Barrierer identifisert i markedet oppstår hovedsakelig grunnet mangel på markedsstruktur og nasjonale regulatoriske standarder. Empirisk data tilsier at statlig tilrettelegging kan bidra og være en avgjørende katalysator for videreutvikling av det norske markedet for gjenbruk av brukte EV-batterier.

Nøkkelord: Lithium-Ion Batterier; Brukte elbilbatterier; Gjennbruk; Strategiske faktorer; Forskriftsmessige standarder.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

B2B Business to Business. 48
B2C Business to Consumer. 48
BESS Battery Energy Storage Systems. 14, 15, 36, 38–42
BMS Battery Management System. 10, 11, 24, 42

CE Circular Economy. 5, 16, 17, 38

EC European Commission. 1, 23, 59
EoL End of Life. II, 1–4, 9, 11, 12, 17, 20, 22, 24, 43, 47, 49, 54–56, 58, 59
EPR Extended Producer Responsibility. 13
ESS Energy Storage Systems. 4, 5, 9, 13, 15, 16, 24, 25, 30, 35–38, 40–42, 47, 48, 53, 54
EU European Union. 23
EV Electric Vehicle. II, III, 1–6, 9–14, 16, 17, 20, 22–24, 36–38, 40–48, 51, 54–56, 58

LFP Lithium Iron Phosphate. 10, 45
LIB Lithium-Ion Batteries. II, III, 1–3, 5–7, 9–13, 17, 18, 22, 27, 30, 31, 36, 38–40, 42, 45, 47, 59, 62, 63
LMO Lithium Manganese Oxide. 10

NCA Nickel Cobalt Aluminum Oxide. 10
NMC Nickel Manganese Cobalt Oxide. 10

OEM Original Equipment Manufacturer. 1, 3, 10, 13, 14, 17, 19, 22, 36, 37, 41, 42, 44, 45, 47, 49, 53, 55–57, 59, 60, 63

SoH State of Health. 10

1 | INTRODUCTION

In 2020, the European Commission (EC) presented an upgraded plan to meet the United Nation's climate targets set by The Paris Climate Agreement in 2015. The main goal was to reduce climate gas emissions by a minimum of 55% compared to 1990-levels within 2030. Several actions have been presented to achieve this goal, including policies for energy efficiency and renewable energies and consolidating CO_2 standard for vehicles. These actions have in recent years contributed to a boost in the global electrification of the transport sector, leading to a significant increase in Electric Vehicles (EVs) (Bibra et al., 2021).

In 2020, the global stock of EVs increased by 43% compared to the previous year, making it count for a total of 10 million EVs worldwide. In Europe, EVs counted for 3.2 million vehicles in 2020, and for the first time, surpassing China in terms of annual increase. In Norway, EVs represented a share equal to 75% of all cars registered in 2020, representing the country in the world with the highest EV market share at 55% (Bibra et al., 2021).

The modern EV is equipped with Lithium-Ion Batteries (LIB), providing high energy and power density, low self-discharge rate, and long lifetime. EVs are expected to contribute to the reduction in climate impact, and pollution problems originated from the transport sector. Moreover, these batteries are built consisting economic valuable and scarce raw materials, making it a global issue to exploit their energy potential (Olsson et al., 2018). A LIB reaches its End of Life (EoL) and is decommissioned from the vehicle by the Original Equipment Manufacturer (OEM) when the retaining maximum energy capacity drops below 80% compared to its original capacity. Current methods for handling decommissioned batteries include disposal, repurposing, and recycling (Or et al., 2020).

The rapid increase in EVs leads to an increase in a number of decommissioned LIBs, which in recent years has created value for several start-ups, by employing EoL LIBs in second-life applications. An article from McKinsey & Company reports that the continued global growth of EVs could generate 200 GWh in energy storage systems by 2030 (Engel et al., 2019). Examples of applications for second-life batteries are; wind and solar power storage, peak shaving, EV charging, increasing grid capability and stability, power backup, electricity trading, and vehicle thrust (Olsson et al., 2018).

Norway is a first-mover internationally with a high EV market share, meaning that the amount of EoL batteries will increase in the coming years (Energy Agency, 2021). There are already a few Norwegian businesses established in the energy storage markets, aiming to repurpose decommissioned LIBs from EVs. A look into the market reveals that these businesses are mainly start-ups, contributing to incorporating second-life LIB into a circular battery value chain.

In this thesis, a selection of these established businesses will be studied in terms of their strategic choices, accessible monetary incentives, and limitations and drivers from regulatory standards. This thesis aims to understand and gain knowledge about their experiences in the battery value chain, their differences in strategies, and what incentives affect their operations. The desired output should help the industry create new business propositions and improve batteries' overall circularity and ecological footprint. Furthermore, utilization of second-life batteries can also lead to lower demand for first-use batteries in energy storage applications, extending the battery life cycle and reducing environmental impacts from raw material mining (Faessler, 2021).

1.1 LITERATURE OVERVIEW

Previous literature has addressed several areas cornering the use of retired EV batteries. While some has focused on potentials for second-life EV battery utilization (i.e., Hua et al., 2021; Hua et al., 2020; Idjis & da Costa, 2017), others have seeked out what business models are being used by the stakeholders in the second-life EV battery market (i.e., Bräuer et al., 2016; Jiao, 2017; Jiao & Evans, 2018; Klör et al., 2015; Lih et al., 2012) and what business models that are best suited for the second-life EV battery market from a theoretical point of view (i.e., Bräuer, 2016; Jiao & Evans, 2016). In the area concerning regulations and policy, researches have looked towards what barriers and challenges that are related to the repurposing of EV batteries (i.e., Albertsen et al., 2021; Hellström & Wrålsen, 2020; Mir Mohammadi Kooshknow et al., 2020; Olsson et al., 2018; Zhao et al., 2021). A full overview of the listed literature are found in Tables 1.1 to 1.3.

Table 1.1. Review of previous literature cornering potentials for second-life utilization of LIBs.

Literature	Reviews
Hua et al. (2021)	Addresses the use of LIBs in energy storage technologies. Current methods for decommissioned batteries are; disposal, recycling, and reuse. The article presents a variety of second-life applications to obtain better economic and environmental benefits. The reuse aspect should consider environmental, economic, and technical market perspectives. Technical issues that must be addressed are safety issues, evaluation methods, technologies for screening and restructuring, and comprehensive management of the reuse process.
Hua et al. (2020)	Provides a discussion of the LIB circular value chain. The article proposes a 5R principle; reduce, redesign, re-manufacturing, repurpose, and recycle in the circular value chain process. Further, second-life applications, technologies for re-manufacturing, and a summary of key challenges are presented in detail. At last, the article discusses technologies for battery recycling from technical, economic, and regulative perspectives.
Idjis and da Costa (2017)	Highlights the economic aspect of LIB EoL recovery. An analysis of cost evolution is performed in order to determine if LIBs is a source of cost or profit for OEMs. In addition, the article analyses the two scenarios, recycling, and repurposing, presenting the total outcome for costs. Findings show that repurposing could lower the battery's initial cost, while recycling might increase it.

Table 1.2. Review of previous literature cornering business models best suited for second-life EV batteries.

Literature	Reviews
Jiao and Evans (2016)	Presents business models for different stakeholders, facilitating battery reuse. Through analyzing how battery reuse can facilitate sustainable innovation for EV industry business models, the findings highlight the value of battery ownership, partnerships in the industry, and policy support regarding secondary use of decommissioned EV batteries.
Jiao (2017) and Jiao and Evans (2018)	Explores utilized business models for re-purposed second-life EV batteries. Based on empirical interview data, three business models are noted: Standard-, Collaborative- and Integrative Business Model(s). Jiao and Evans (2018) poses three critical design elements for business models dealing with repurposed EV batteries; life-cycle thinking, system-level design, and shift to services.
Bräuer (2016)	Examines the challenges of second-life battery utilization across the battery life cycle. The report states that establishing mature business models for second-life batteries still needs development and suggests a product-service system to counter the related uncertainty. The list of challenges was based on a literature review lacking empirical evidence. The potential value of second-life batteries was also not discussed against the challenges identified.
Beer et al. (2012)	Analyzes the possibility of extending the life cycle of EV batteries with employment in second-life applications. The report proposes three different business models addressing the added value of storage capability for EV batteries in second-life Energy Storage Systems (ESS). In the end, a comparison in different levels of battery integration with the building of an ESS was made without investigating value creation and capture of second-life batteries.
Bräuer et al. (2016)	Reviews already existing business models for German providers of residential ESSs. The report suggests a re-design for second-life batteries in order to open up a market for ESSs built with EoL batteries from EVs. The model is based on offering value-added services to compensate for spent batteries' defects and show their quality.
Klör et al. (2015)	Investigate and conceptualizes three possible forms of a market for trading EoL batteries from EVs. The report provides some insight into potential stakeholder relationships regarding second-life batteries. However, it does not examine how the different stakeholders can create and capture value from second-life battery utilization.

Table 1.2. Continued from previous page.

Literature	Reviews
Lih et al. (2012)	Suggests to design an optimal business model for second-life batteries. The suggested solution is to sell the EV exclusive of the battery but lease the battery itself. It is clear that the report is offering a sales model for EVs and does not design a business model for second-life battery utilization.

Table 1.3. Review of previous literature cornering barriers and challenges related to repurposing of EV batteries.

Literature	Reviews
Mir Mohammadi Kooshknow et al. (2020)	Three barriers for ESSs were identified; technical, low penetration of variable renewables in the ESSs, and economic and business challenges. It is argued that by covering the third challenge, a positive propagation would influence both the first and second sets of challenges.
Hellström and Wrålsen (2020)	Highlights challenges and barriers related to business ecosystems and business models that facilitates Circular Economy (CE) around LIBs in Norway and Europe.
Olsson et al. (2018)	Explores how battery value chain and business models for second-life EV batteries can be more circular. Organizational and cognitive barriers, and opportunities, for second-life batteries, are identified through interviews and workshops with stakeholders, and new business models are conceptualized. The report concludes that actors in the battery value chain should collaborate with additional actors to benefit from creating new business opportunities, including developing new models in cooperation.
Zhao et al. (2021)	Reviews the current global battery market and waste status and discusses battery repurpose and recycling. The article also presents the inherent challenges, opportunities, and arguments on battery repurpose and recycling. At last, a summary of recent research on the respective topics is provided to draw a landscape and give valuable insight into the repurposing and recycling for industries, research, and waste management.
Albertsen et al. (2021)	Addresses CE strategies for LIBs and their current adoption among European vehicle manufacturers.

1.1.1 Research gap

The reviewed literature has had great focus on the potentials for second-life utilization of LIBs (i.e., Table 1.1), business models best suited for second-life EV batteries (i.e., Table 1.2), and barriers and challenges related to repurposing of EV batteries (i.e., Table 1.3). Hence, the literature indicates that second-life battery repurposing is a topic that rapidly adopts new technological development and novelties. This rapid adoption and the novelty of the research allows for several research opportunities and -gaps to be found and covered. In this thesis' research, a focus on the Norwegian market will be the point of interest. This focus is viewed as both topical and appropriate as the Norwegian EV market share is the world's highest, as stated earlier in the introduction.

With this geographical limitation, the thesis will explore the second-life battery repurposing market based on existing research on utilized business models in the respective market. Moreover, drivers that could amplify business opportunities in the second-life battery market have not yet been investigated. Hence, by combining drivers and barriers of monetary incentives and regulatory standards, this thesis aims to contribute with empirical evidence gathered from the actors of today's Norwegian second-life battery repurposing market.

Therefore, this thesis will try to close the respective research gap and contribute to the field of research with insight from empirical data and be a point of reference for potential companies interested in forming a business in the second-life battery repurposing market.

1.2 RESEARCH QUESTION

Based on the described research gap, two themes are identified and will be the starting point of the research to define the research questions further. These two themes are recognized as *internal* and *external* aspects. The internal aspect recognizes the strategic factors currently used by businesses residing in the Norwegian second-life LIB market. This thesis defines *strategic factors* as "those activities a business needs to perform right to create value for its stakeholders:

customers, shareholders, employees, suppliers, and other businesses". Secondly, the external aspect is recognized as monetary incentives and regulatory standards that can contribute to the enhancement of success for second-life LIB utilization. with these two aspects accounted for, the following research questions can be formulated:

RQ1: Which strategic factors are being used today in the Norwegian market for second-life battery repurposing, and how do they compare to the existing theory in this field?

RQ2: What monetary incentives and set of regulatory standards are identified in the Norwegian market for second-life battery utilization?

RQ2.1: How are these factors seen as barriers?
RQ2.2: How are these factors seen as drivers?

1.3 THESIS STRUCTURE

Following is an overview of the thesis's six chapters explaining their aims, objectives, and outcomes.

Chapter 1 aims to provide an overview of the research by introducing the research's background and relevance both from a global and national perspective. Furthermore, an overview of the literature's current state is provided, and a literature gap is identified. Lastly, the research questions are proposed, and the thesis structure is illustrated.

Chapter 2 has the objective of providing an in-depth presentation of relevant theoretical concepts. The theoretical concepts build upon the literature review and are grounded in the research questions presented in Chapter 1.

Chapter 3 aims to present the methodical choices taken for this thesis. The chapter presents the logic behind the design choices, a step-wise overview of the conducted processes, and choices regarding selecting informants and cases. Finally, the chapter explains how the data was collected and analyzed.

Chapter 4 consists of two main sections; a within-case analysis (Section 4.1) and a cross-case analysis (Section 4.2). The within-case analysis presents each case and its initial findings separately before the cross-case analysis investigates and presents patterns and findings that emerge across the cases.

Chapter 5 aims to provide a discussion of the empirical findings in relation to the theoretical concepts, as well as present new findings. The chapter also aims to present the authors' reflections on the significance of the findings and the implication these findings could have on the existing theory. Finally, the research's contributions and limitations will be discussed.

Chapter 6 has the objective to conclude this research by providing a summary that addresses the key findings as answers to the research questions. The chapter further addresses opportunities for future research based on the discussed limitations and discovered findings.

2 | THEORY

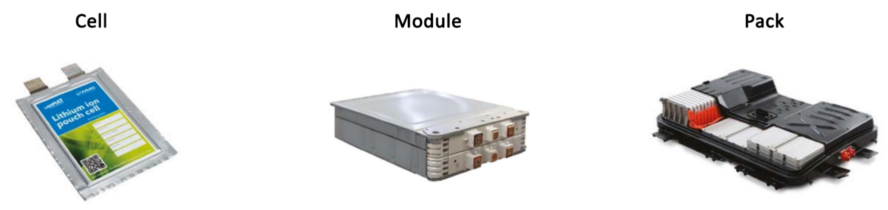
A relevant selection of theoretical background has to be presented to cover the gap identified in Section 1.1.1. This chapter covers several key concepts within second-life batteries and business strategies. First, a fundamental understanding of LIBs is provided (Section 2.1). Second, the life cycle of a battery (Section 2.2) gives insight into the three life cycles a LIB goes through, namely; First-life (e.g., EV use), second-life (e.g., ESS use), and EoL where the unit no longer can be utilized and is therefore sent to recycling. Third, a deeper insight into the reason for repurposing second-life batteries (Section 2.3) is presented, including four possible second-life applications for decommissioned EV batteries. Fourth, theoretical background for circular economy (Section 2.4) and strategies for circular design (Section 2.5) is presented. Following, relevant business models (Section 2.6) are elaborated before incentives and regulatory standards (Section 2.7) for the Norwegian second-life battery market are addressed. Finally, existing barriers identified from the literature are presented (Section 2.8).

2.1 LITHIUM-ION BATTERIES

Lithium is reviewed as the most favorable metal to use in commercial EV batteries. It has the advantage of allowing a high energy storage potential and long cycle life, providing an EV with increased distance and performance (Pagliaro & Meneguzzo, 2019). However, because of the high reactivity that lithium possesses, producers have developed EV batteries containing lithium in the form of lithium-ions, avoiding technical challenges related to the reactivity. A LIB cell consists of four main components; a cathode, anode, electrolyte, and a separator. When charging a LIB cell, lithium-ions advance from the cathode to the anode through the electrolyte. When discharging, the lithium-ions move in the opposite direction, distributing electric energy to power the application the battery is deployed in. The battery is named after lithium-ion, the primary determinant for the cell's properties. Having lithium as the primary determinant, the technology is also combined with different metal oxides: Nickel Manganese Cobalt Oxide (NMC), Nickel Cobalt Aluminum Oxide (NCA), Lithium Iron Phosphate (LFP), and Lithium Manganese Oxide (LMO) (Zubi et al., 2018).

The variety in chemical build-up for LIBs results in different characteristics (Zubi et al., 2018). LIBs are characterized by their capacity, safety, and durability, and their lifespan and effectiveness are affected by various factors. Degradation in battery performance happens over time by loss in capacity or power through deployment in applications such as EVs (Miao et al., 2019). The overall State of Health (SoH) is a parameter to measure the remaining capacity in a LIB. Typically, LIBs deployed in EVs is decommissioned when reaching 80-70% SoH (Montoya-Bedoya et al., 2020).

A LIB found in an EV is separated into three different levels and a Battery Management System (BMS). The levels are referred to as battery pack, battery module, and battery cell (Pagliaro & Meneguzzo, 2019). The different levels found in a battery pack for EVs are illustrated in Figure 2.1. The lowest level is the individual battery cell illustrated in Figure 2.1a. Cells of different styles can be found in different battery packs, depending on the OEM (Faessler, 2021; Pagliaro & Meneguzzo, 2019). Figure 2.1b shows when multiple cells are assembled to constitute a battery module. Further, a battery pack is illustrated in Figure 2.1c, where modules are assembled with additional components, creating the unit that distributes electric power to the vehicle.



(a) Cell level. **(b)** Module level. **(c)** Pack level.

Figure 2.1. The different levels of a battery pack that are found in electric vehicles. This is an example from a Nissan Leaf EV. Figure obtained from Bjønnes et al. (2020).

For the BMS, the task is to ensure a safe operation when charging and discharging the battery pack. By monitoring the pack and accompanying components related to energy transfer, the BMS is in control of the electrical distribution to the application it is deployed in. Meaning that if deployed in an EV, the BMS is essential to ensure proper energy distribution and temperature of the pack so that the driver can operate a safe vehicle (Hannan et al., 2018; Wang et al., 2016).

2.2 BATTERY LIFE CYCLE

Production of LIBs engages several industries, from raw materials to employment in EVs. The life cycle of an EV battery connects industries such as mining of raw materials, chemical industries, metal industries, and electronic industries along the chain, creating value opportunities in all stages (Zubi et al., 2018). Jiao and Evans (2018) identifies life cycle thinking to help stakeholders understand potential value creation and opportunities along the chain to better design suitable business models. Figure 2.2 illustrates the battery life cycle, showing multiple lives in a broader sense. Battery first-life, Battery second-life, and Battery EoL.

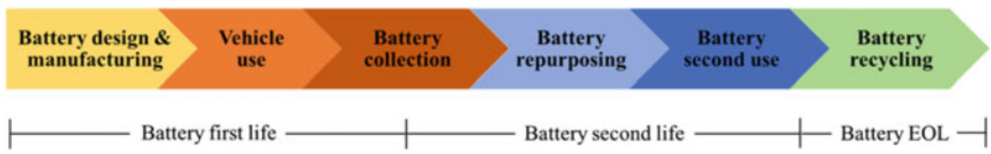


Figure 2.2. Key stages of the battery life cycle. Obtained from Jiao and Evans (2018, p. 336)

Battery first-life is referred to as design and manufacturing, employment in EVs, and return for collection when decommissioned from the vehicle. Battery second-life includes collection, repurposing, and second-life reuse in lower demanding applications. The repurposing process includes testing, battery-pack disassembly, and replacement of eventual damaged modules or cells. It may also be necessary to reconfigure the structure of the battery pack or change hardware and software, depending on the reuse application (J. Yang et al., 2020). Battery EoL represents the stage when the unit can no longer be utilized. Point of EoL depends on the conditions after first-life use and operation profile during employment as second-life battery (Jiao & Evans, 2018).

Figure 2.3 illustrates the detailed process from the moment a LIB reaches its EoL in, e.g., an EV, and to the battery is ready for deployment in a second-life application. The battery pack is removed from its first-life application when reaching approximately 80% of its original capacity before being shipped to a battery repurpose company. When receiving a second-life battery, the repurposer has to test and evaluate the battery pack to ensure safe handling and operation in a second-life application. The pack can be disassembled into modules and components when verified as a safe and usable battery. After the recyclable components are consolidated, the modules undergo testing to identify capacity and characterization. This testing is critical to know if the modules can operate in an application. Modules are sent to recycling if they cannot meet the criteria, while verified battery modules are ready for installation in a second-life application (Hossain et al., 2019; Warner, 2015).

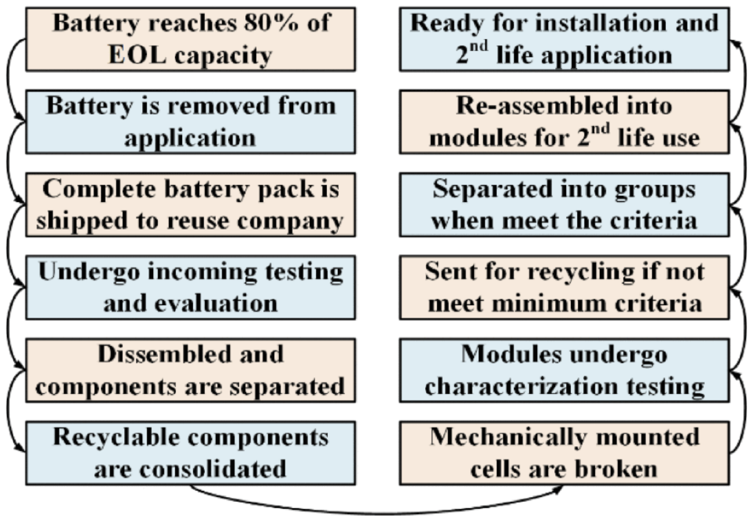


Figure 2.3. A detailed process of preparing LIBs for second-life purposes. The process includes detailed sequences in order to create proper second-life ESSs. Figure is obtained from Warner (2015, p. 172)

2.2.1 Ecosystem for second-life batteries

Adner (2017) defines an ecosystem as “The alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize” (Adner, 2017, p. 40). In such a system, actors have defined positions and flows of activity that connects them (Adner, 2017). Hellström and Wrålsen (2020, p. 13) addresses following actors when modeling an ecosystem for LIB second use:

- Battery Component and Pack Producers
- Automotive OEMs
- Car Dismantlers
- Battery Dismantlers
- Battery Repurposers
- System Integrators/ESS Providers
- Grid Owners and Operators

In such an ecosystem, the EV battery is affected by Extended Producer Responsibility (EPR) regulations. Meaning that the OEMs are responsible for the handling of decommissioned batteries. The handling is typically done by an EPR contractor, coordinating the collection of batteries and assigning a recycling company for safe handling (Hellström & Wrålsen, 2020). Figure 2.4 illustrates the value stream of spent Norwegian EVs. Blue arrows show monetary flows, and black arrows show physical flows.

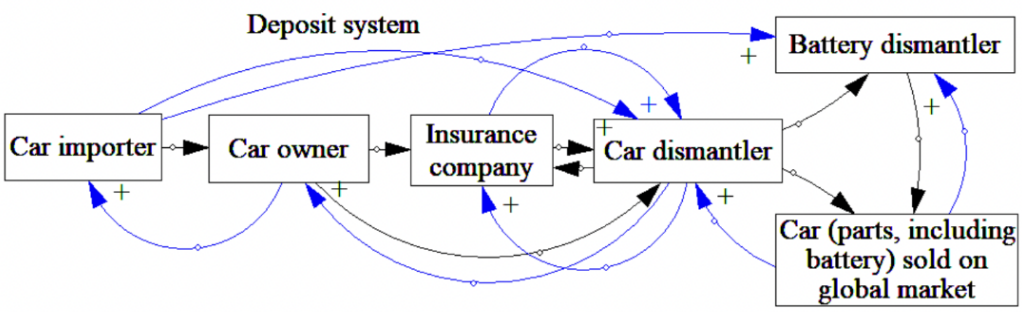


Figure 2.4. Illustration of the Norwegian spent car value stream. Obtained from Hellström and Wrålsen (2020, p. 14)

The Norwegian deposit system is recognized as unique in Europe, having a compelling collection of decommissioned EV batteries. This deposit system means that as an OEM, entering the Norwegian EV market, the system forces adoption of this model. Moreover, compared to other European countries, it is regarded as more challenging to manage the EV battery when decommissioned from the vehicle (Hellström & Wrålsen, 2020).

2.3 SECOND-LIFE BATTERY REPURPOSE

Disposal of EV batteries leads to great waste in natural resources and raw materials, contaminating the environment (Schneider et al., 2009). The concept of repurposing batteries is recognized as a strategy to avoid disposal and maximize the value of EV batteries in a circular approach before recycling (Jiao & Evans, 2018; Pagliaro & Meneguzzo, 2019). Batteries are retired from employment in EVs after 20%-30% of the initial capacity has been lost. Its lower current density makes it unsuitable to deliver the promised EV performance, and is decommissioned and collected by the OEM (Hellström & Wrålsen, 2020; Pagliaro & Meneguzzo, 2019). Depending on the cell chemistry, design, or assembly, these batteries can still be used in lower energy-demanding applications (Faessler, 2021).

2.3.1 Second-life applications

Decommissioned EV batteries can be employed in a wide range of applications. This subsection presents an overview of such applications. After the end of their automotive life cycle, EV batteries can be repurposed in secondary energy storage applications, such as peak shaving, load shifting, swapping power stations, and renewable energy storage (Hua et al., 2021; J. Yang et al., 2020). As Europe looks toward a sustainable future, the increased electrification causes high stress on the electric grid, creating an urgency for expansion, upgrade, or measures to compensate for the imbalances between the supply and demand of electric energy. Stationary Battery Energy Storage Systems (BESS) has been identified as one central element to improve the electric grid's buffer capacity. Batteries can be used to balance the supply and demand, e.g., through energy-storing of solar or wind energy, to be consumed when needed (Faessler, 2021).

Residential applications. For residential applications, most of the electricity demand goes to the powering of electrical appliances for water and room heating, which varies throughout the day. By integrating renewable energy sources with the grid, such as solar panels, the electricity demand can be met when generating energy from the sun. During the evening and night, however, there is no generation: Creating a necessity to use an ESS, for example, with batteries (called BESS). With the cost in mind, ESSs with second-life batteries is a suitable solution to the problem. Moreover, such a solution enables the possibility of generating electric power, storing it, and using it at a later time (Hossain et al., 2019).

Industrial and commercial applications. Electrical demand for industrial and commercial facilities is, on average, a lot higher than for residents. The peak demand is identified to occur in the middle of the day. Although the conditions for generating energy from the sun are good at this time, solar panels cannot consistently deliver what is needed. Furthermore, as the industrial and commercial load is high, peak shaving applications would be beneficial to implement. Employment of second-life batteries in ESS can store the electric power and be used to supply facilities during peak periods, reducing high costs and leveling out the load on the grid (Hossain et al., 2019; Warner, 2015).

Grid applications. The ever-increasing number of second-life batteries can lead to large disposal of battery packs in the Megawatt-hour range applicable to stationary grid utilization. By utilizing second-life batteries in connection to grids, an effectively reduce in peak load can be achieved. This application can further enable consumers to optimize energy demand patterns according to conditions in the market, optimizing energy consumption. Renewable energy farming, energy arbitrage, and area- and frequency regulations are examples of applications for stationary grids. In addition, renewable energy sources have become more popular for off-grid applications, where micro-grids provide power to remote areas due to environmental and economic benefits. With the intermittent nature of renewable energy sources, a second-life battery ESS can ensure stability for the power system, as well as provide backup power (Hossain et al., 2019; Warner, 2015).

Mobile applications. ESSs with second-life batteries can also be utilized in EV charging stations. The increasing market share of EVs is causing scarcity for charging infrastructure. Second-life batteries can provide interim storage and power buffering for fast-charge stations. With a remaining capacity of 70-80%, second-life batteries can also be employed in a shorter range EVs (Hossain et al., 2019).

2.4 CIRCULAR ECONOMY FOR LITHIUM-ION BATTERIES

Sustainability issues (i.e., environmental problems affecting the earth's life systems, societal expectations that are not met, and economic challenges) have gained global awareness due to the instabilities of the individual companies and the entire economy over the last decade. Circular Economy (CE) have thus received increased importance as a tool to address these issues. Furthermore, the concept has also developed into a hot topic in academic studies, as well as increased awareness by companies and their opportunities regarding circular value creation (Geissdoerfer et al., 2017; Zhao et al., 2021).

CE is the concept of turning goods at the end of their life into new resources in order to close loops and minimize waste. The concept's logic is to reuse what can be reused, recycle what cannot be used, repair what is broken, and re-manufacture what cannot be repaired (Stahel, 2016). Geissdoerfer et al. (2017) defines CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, re-manufacturing, refurbishing, and recycling." (Geissdoerfer et al., 2017, p. 759). Specific dimensions of CE are supply chains, circular business models, circular product design, and closed-loop value (Geissdoerfer et al., 2017).

In order to achieve the Paris Agreement's 2°C goal in the transport and power sectors, a circular battery value chain is regarded as an essential contributor. With a circular closed battery value chain, 30% of the required reduction of carbon emissions in the transport and power sectors could be enabled. Figure 2.5 illustrates a general circular value chain, making it adaptable for a battery value chain (Zhao et al., 2021).

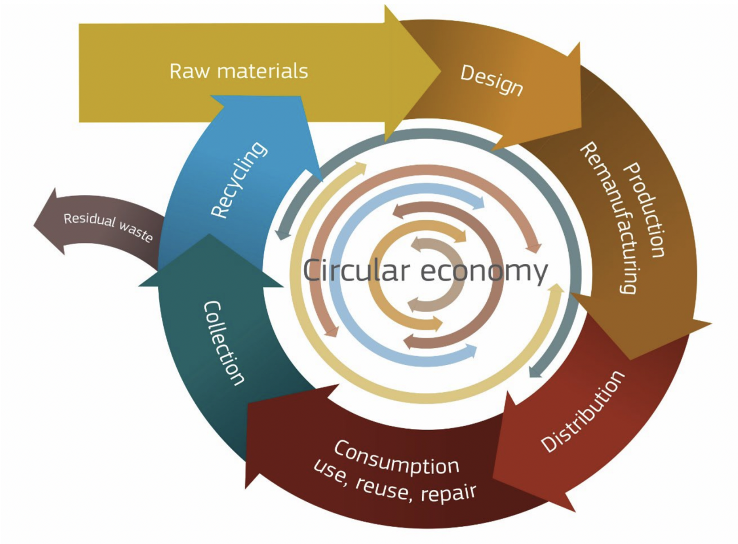


Figure 2.5. A circular value chain, adaptable to value chain for lithium ion batteries. Obtained from European Commission et al. (2018, p. 9)

A circular battery value chain is regarded as the optimal battery value chain, where all activities have to be performed to gain circularity. Raw materials are extracted to design and manufacture LIB packs by the OEM (i.e., the battery producer). The finished product is distributed and employed in an EV by a car manufacturer. When reaching EoL, begins the process of preparing the LIB for second-life utilization as described by Figure 2.3. The repurposing process takes place takes place in *Consumption; use, reuse, repair* in Figure 2.5. After being utilized in a second-life application, the LIB is collected and sent to recycling. The recycling process recovers materials, ready to be used in the production of new LIBs, before being deployed again in an EV (Ahuja et al., 2020; Hua et al., 2020; Zhao et al., 2021).

2.5 STRATEGIES FOR CIRCULAR DESIGN

Circular design and CE strategies are listed from Bocken et al. (2016) in three different resource cycles. The approaches are named as *Slowing resource loops*, *Closing resource loops* and *Resource efficiency or narrowing resource flows*. Whereas the first two focus on a longer use case of the product or full utilization of the product's materials between post-use and production, respectively, the last resource cycle differs, intending to use fewer resources in the production. A focus on the slowing of resource loops is what would be most appropriate for LIBs (Albertsen et al., 2021).

For a business to maximize its battery usability for second-life repurposing, the business of incorporating design strategies for slowing resource loops is a possibility (Bocken et al., 2016). Listed below are the relevant strategies for slowing resource loops (adapted from Bocken et al., 2016, p. 310):

- Designing long-life products
  - Design for attachment and trust
  - Design for reliability and durability
- Design for product-life extension
  - Design for maintenance and repair
  - Designing products to allow for future expansion and modification
  - Design for standardization and compatibility
  - Design for dis- and reassembly

2.6 BUSINESS MODELS

Casadesus-Masanell and Ricart (2010) introduces the concepts of strategy, business model, and tactics separate before combining all three concepts in one integrated framework. For the framework, they note that a firm's strategy "[...] entails designing business models (and redesigning them as contingencies occur) to allow the organization to reach its goals." (Casadesus-Masanell & Ricart, 2010, p. 204). As Figure 2.6 illustrates, tactics are noted as a "competitive choices enabled by each business model" (Casadesus-Masanell & Ricart, 2010, p. 204). Hence, the level of tactics can be seen as similar to strategy-business model relation but on a lower and more detailed level.

Business models have received more attention in the last couple of decades, but a conscientious on a single model or framework among the researchers has not been reached. Moreover, as businesses differ quite a lot, so does their business model, making it difficult to reach a union agreement on *must have* properties for a business model. However, some literature has gained more attention than others. Table 2.1, on p. 21, provides an overview of the different key elements and components that are viewed as a necessity according to their cited literature.

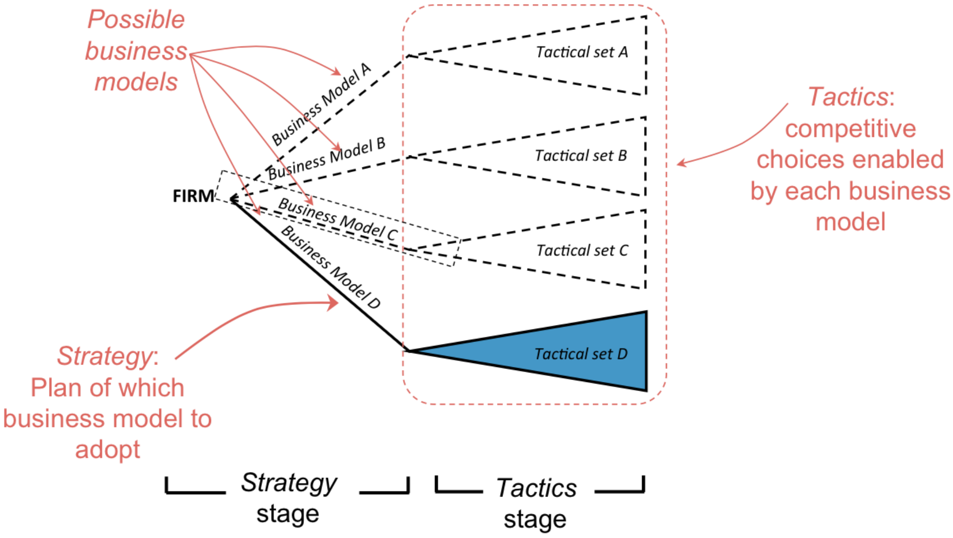


Figure 2.6. Relation between Strategy, Business model and Tactics. Obtained from Casadesus-Masanell and Ricart (2010, p. 204).

With more stakeholders joining the second-life battery repurposing market, Jiao (2017) proposes future research to investigate emerging stakeholders (e.g., start-ups) to enrich research regarding business models for second-life battery repurposing and the value of second-life battery repurposing for multiple stakeholders.

Jiao (2017) and Jiao and Evans (2018) examines seven cases related to the second-life repurposing of batteries and categorizes the current business models. Figure 2.7, on p. 20, illustrates how their cases compare to each other in respect of collaboration between the OEM and the second-life battery solution provider, as well as to the degree of integration the OEM has to the second-life battery solution provider. For the latter, it means that the higher the box of the OEM is, the greater the integration is.

Viewing Figure 2.7 and the research of Jiao and Evans (2018) in correlation to the literature of Casadesus-Masanell and Ricart (2010), different cases has chosen different key strategic factors resulting in different business models. Furthermore, these different business models allow for different value propositions by varying their collaboration with the OEM.

Jiao and Evans (2018) further discusses aspects for better business model design when dealing with second-life battery use. Their discussion shows that even more benefits for second-life battery use can be achieved through a high level of life cycle thinking. Their findings identify that all seven case studies did not maximize their benefits for the second-life use case of the battery. As batteries are solemnly designed for their second-life use case, a value analysis reflecting upon the battery's whole life would be beneficial. With "the battery's whole life", it is meant the battery's initial design and life, i.e., EV use, to the battery's repurposing and second use, and in the end, the battery's recycled stage and its EoL.

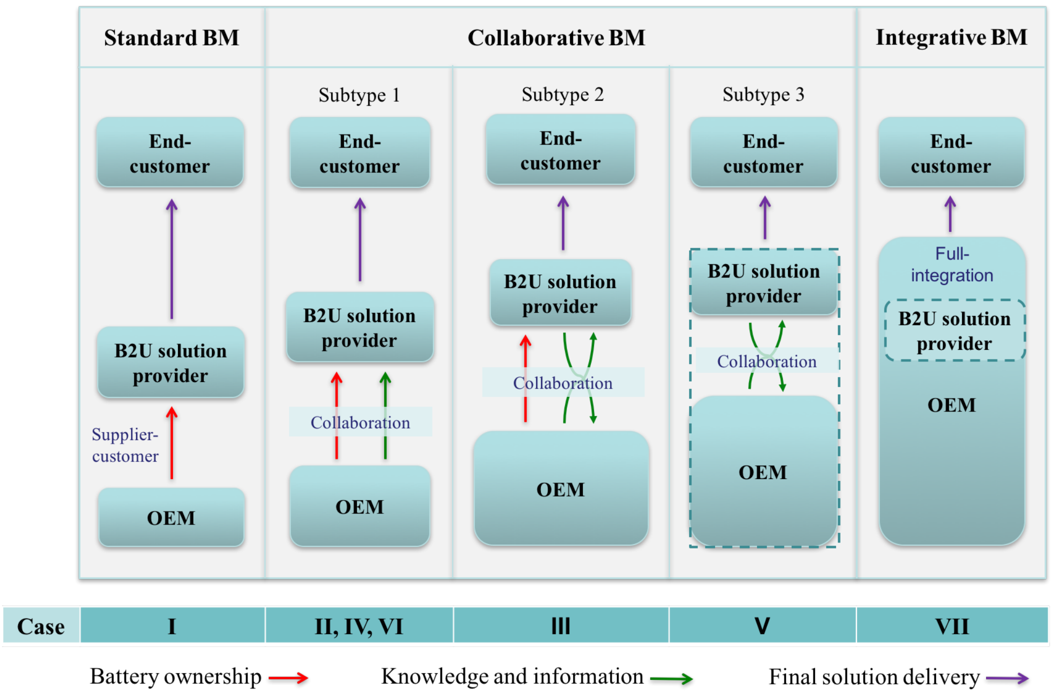


Figure 2.7. A schematic typology of business models for second-life battery use. Obtained from Jiao (2017, p. 173) and Jiao and Evans (2018, p. 327).

Table 2.1. An overview of key elements and components, according to cited literature, that are viewed as a necessity for business models.

Literature	Key elements/ components	Summary
J. Richardson (2008)	• Value proposition • Value creation and delivery • Value capture	A proposal of business model framework to link with a firm's theory on how they can compete to their execution. The framework aims to be a useful tool for teaching, research and for the strategist. The paper identifies the value proposition (Offering, target customer, basic strategy), value creation (resources, capabilities, organization, position in the value network) and value capture (revenue source, business economics) as main components of a business model.
Johnson et al. (2008)	• Customer value proposition • Profit formula • Key resources • Key processes	This article describes the definition of business models, using a four-element framework: Customer value framework (solving customer problems to satisfy their needs), profit formula, key resources (resources needed) and key processes.
Morris et al. (2005)	• Offering • Market • Internal capability • Competitive strategy • Economic • Personal/investor factors	This article synthesizes literature and draws conclusions applying a six-component framework to characterize a business model regardless of business type. The model proposed allow users to categorize, criticize, design, describe and analyze any venture's business model.
Osterwalder and Pigneur (2010)	• Key partners • Key activities • Key resources • Key propositions • Customer relationship • Channels • Customer segments • Cost structure • Revenue streams	This handbook proposes a business model canvas, providing structure to overcome shortcomings of the traditional approach. Consisting of nine blocks, the model defines all sorts of commercialization that create value for both customers and organizations.

2.7 INCENTIVES AND REGULATORY STANDARDS

The purpose of incentives is to motivate or drive an employee or an organization to perform an action or behave in a certain way. Two main types of incentives are introduced, intrinsic and extrinsic incentives. Intrinsic incentives motivate one to act out of one's desire or self-interest without promised rewards or pressure. In contrast, extrinsic incentives motivate by rewards, i.e., an increased pay rate for achieving result goals (Armstrong, 2010). Several incentives have been introduced in Norway to encourage adoption of the EV fleet, but very few for second-life battery applications (Song & Potoglou, 2020). This thesis divides applicable incentives into four main categories, depending on their scope and who declares them: monetary incentives, non-monetary incentives, national targets, and regulations.

2.7.1 Monetary incentives

Monetary incentives refer to money as a reward for doing an action or specific behavior. It might not always be the best one, but the use of monetary incentives is common (Merchant & Van der Stede, 2007). Monetary incentives can reduce the price gap between products, making sustainable alternatives more favorable. Tax benefits, purchase subsidies for investing in second-life applications, charging subsidies, and industrial subsidies are sets of monetary subsidies that could be introduced for second-life applications. Norway has implemented these incentives for EV owners but is yet to present for second-life applications (Song & Potoglou, 2020).

The research of Idjis and da Costa (2017) indicates the importance of incorporating repurposing of LIB to minimize costs and, within the perfect conditions, also profit on the global EoL in the long term. By incorporating repurposing rather than shipping the batteries straight to recycling, long-term global EoL costs can be reduced by up to 11%, while in a worst-case reduced by 6%. Hence, incorporating battery repurposing either directly within the business of the OEM or by other third-party firms should imply a profitable long-term business.

2.7.2 Non-monetary incentives

Professionals have been resistant to acknowledging that non-monetary incentives work as strongly as monetary incentives. Non-monetary incentives can be a robust intrinsic motivator, creating a willingness to perform (Sorauren, 2000). It can be effective in the long run when the price gap between first-life batteries and second-life batteries is not a significant barrier (Song & Potoglou, 2020).

2.7.3 National targets

National targets are leading key players in government mechanisms. It can be seen as policies for action adopted or proposed by the state and can play a role when accelerating the penetration of a service or product. For example, in regards to second-life batteries, national targets can contribute to a shift in national focus, increasing the market share and improving the distribution of the service or product (Song & Potoglou, 2020).

2.7.4 Governing regulations

Government regulations refer to requirements for manufacturers and consumers. They are laws that control which ways a business can operate and can be backed by the use of penalties, often for the intention of modifying economic behavior (Song & Potoglou, 2020).

EU battery directive

The EC has presented a new battery directive in order to ensure sustainability for EV batteries on the European market. Regulations is indeed needed and intends to develop a robust European battery value chain and industry. A new proposal (European Commission, 2020) repeals the 2006 European Union (EU) directive (European Commission, 2006) (for current consolidated version, see European Commission, 2018), to address the challenges of today.

The proposal aims to increase traceability and transparency throughout the battery value chain. Moreover, it addresses the impact on climate by requiring mandatory carbon footprint declarations while also emphasizing concrete actions to develop circularity for raw materials by earmarking the collection and recycling rates of spent batteries. Furthermore, which is highly relevant for this master thesis, is the requirements to optimize performance management and longevity for EoL batteries. These requirements include granted access to the BMS for battery dismantlers in order to control the battery's health to determine the opportunity to be repurposed before recycled (European Commission, 2020).

This thesis will look into the business strategies and monetary incentives used in today's market for repurposing batteries. The Norwegian market will be the main focus for examination as the high EV market share in Norway will potentially mean a jump in the amount of EoL batteries in the coming years. Hence, a study of how to perform a sustainable business in such a market while also motivating stakeholders in the second-life battery industry through incentive systems is seen as a step in the right direction.

The market is yet to reach its full potential. Therefore, this thesis will aim to engage and implicate a transition to more sustainable and competitive ways of conducting business in the second-life battery repurposing market.

2.8 BARRIERS FOR SECOND-LIFE REPURPOSING

Building from Table 1.3, Table 2.2 lists identified barriers and challenges addressed by the literature regarding second-life battery repurposing. First, Jiao (2017) lists barriers in regards to uncertainty, design and regulations. Second, Mir Mohammadi Kooshknow et al. (2020) describes challenges for ESS development. Third, Faessler (2021) addresses those economical, environmental and technological barriers for second-life batteries, as well as the need for regulatory standards. And lastly, Olsson et al. (2018) identifies organizational barriers within businesses, cognitive barriers among customers, and at last lack of technology and legislation.

Table 2.2. An overview of identified barriers according to the cited literature.

Literature	**Barriers**
Jiao (2017)	• Uncertainty to flow of second-life batteries (Supply chain) • Uncertainty to performance of second-life batteries (Technology) • Uncertainty to customers' concern on second-life batteries (Public interest) • Incorporation of design for second-life utilization in original battery design • Lack of market standardization • Lack of market transparency • Lack of subsidies
Mir Mohammadi Kooshknow et al. (2020)	• ESS flexibility (Lack of technology) • Lack of consistent subsidies • Lack of norms and standards • The risk of investing in an ESS
Faessler (2021)	• Economic barriers in regards to the cost-efficiency of ESSs • Environmental barriers in regards to waste management of second-life batteries • Lack of technology to perform automated repurpose process • Lack of regulatory standards
Olsson et al. (2018)	• Organizational barriers • Cognitive barriers • Lack of technology to perform automated repurpose process • Lack of legislation

3 | METHODOLOGY

This chapter intends to reflect upon and shed light on the methodological choices that have been made along the way. Furthermore, a discussion regarding the methodological choices in comparison with other appropriate alternatives to the chosen path will be conducted. The following sections in this chapter will elaborate on the chosen research design, the procedure, and processes performed in this study, the participants in this study, how the data were gathered and what materials that were used, and lastly, how the data were analyzed.

3.1 DESIGN

In this section, the research's design is accounted for, describing the framework of those techniques and methods applied to collect and analyze empirical data logically and coherently to address the research question.

3.1.1 An extensive research design

With the defined problem statement, the thesis' design draws towards an intensive design. Given that the problem is relatively complex, where several variables must be mapped and accounted for, this substantiates the research's design choice for intensive design. However, an extensive design (e.g., using a questionnaire survey) can help the research by including more stakeholders and thus provide better insight into the overall market rather than a selected part of the market. Therefore, another possibility for this thesis could have been to go for both intensive and extensive design. Such a multi-design choice could create solid research with data from many sources and in-depth data from a few sources, clarifying the overall phenomenon being researched (e.g., Creswell, 2014; Lieberman, 2005). On the other hand, it was clarified that this master thesis did not have enough resources to be able to embark on such a design choice (Busch, 2013). Therefore, the choice regarding the research design was to create an in-depth understanding through interviews (see Section 3.4) of seven informants with a direct connection to the phenomenon.

3.1.2 An qualitative approach

Busch (2013) states that quantitative data is well suited for extensive design as it is easier to collect and analyze. While for intensive designs with many variables and few respondents, qualitative data are often preferable as they have rich content and are suitable for analyzing complex contexts (Busch, 2013, p. 58). Potential informants, businesses, and cases viewed as appropriate for this thesis were relatively scarce. This scarcity was somewhat due to the research limitations that required only looking at possibilities in the Norwegian market for second-life battery use cases. With such few possibilities for gaining informants combined with multiple potential informants who declined our invitation for an interview, a quantitative approach would not give sufficient data quality due to few available informants in the selected sampling population (see Section 3.3) for a quantitative approach to be considered appropriate.

Rubin and Rubin (1995) describes the design in qualitative interviewing as iterative, meaning “[...] that each time you repeat the basic process of gathering information, analyzing it, winnowing it, and testing it, you come closer to a clear and convincing model of the phenomenon you are studying [...]” (Rubin & Rubin, 1995, p. 46). So with an intensive design using a qualitative method as the design framework, it is seen as appropriate to examine a relatively new topic that is yet to be addressed with stakeholders in more recent time within the Norwegian market for LIBs repurposing (Morse, 1991).

3.1.3 The time dimension

In regards to the time dimension, Babbie (2010) states that “Researches have two principal options available to deal with the issue of time in the design of their research: cross-sectional studies and longitudinal studies.” (Babbie, 2010, p. 106). This thesis focuses on what is here and now, as well as what might influence the future for repurposing and the second-life of LIBs. With such a focus, the design points more towards a cross-sectional study. However, this research also builds on the results of earlier research and collects data from informants with more than a decade of experience in the field of interest. Hence, this research does not clearly distinguish between being one or the other.

3.2 AN ABDUCTIVE RESEARCH PROCESS

Figure 3.1 provides a graphical overview of the processes conducted in this master thesis. The figure should be seen in combination with the whole of Chapter 3 as it summarizes many of the topics covered here. Furthermore, the following paragraphs describe the main steps, instruments, and techniques used.

Through the ongoing literature review, theoretical and empirical studies were used to build a study-based analysis of the phenomenon. Simultaneously, the case study was built from interviews and, to some extent, secondary data. An iterative approach for the interviews was used where the recent interview (n) altered the following interview ($n+1$).

This ongoing literature review and case study process were iterative in which data and output from the different processes influenced each other. They were then combined in an analytical process, linking relevant data and output.

The output of this analytical process was then used as input for the discussion part and point of reference for our final literature review. The discussion process and the final literature review influenced each other, focusing on making the literature support our discussion topics.

Finally, generating new or enhancing existing theories was carried out. This process was deeply tied with the previous steps and can be seen as a formalization of the already discussed topics.

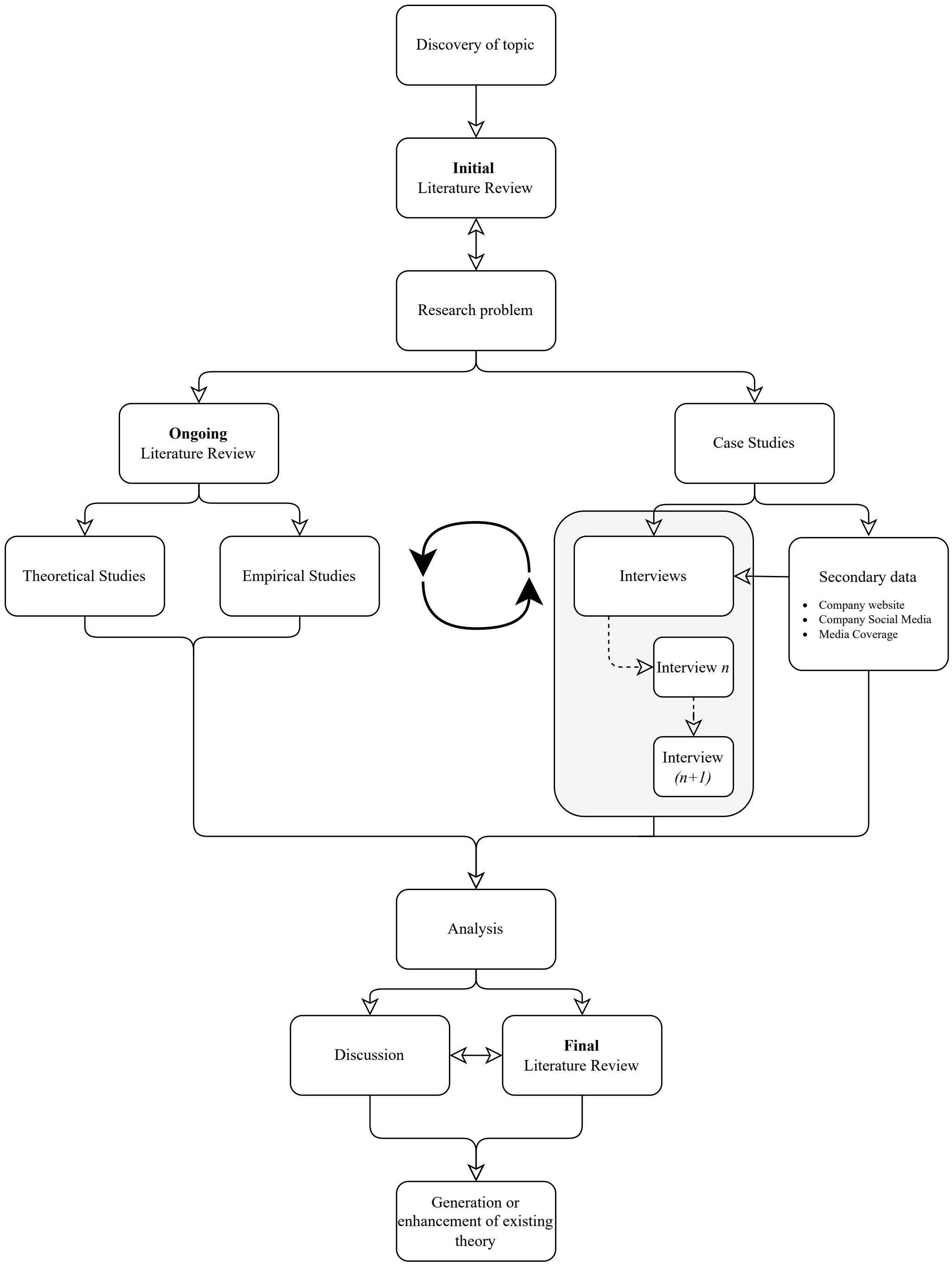


Figure 3.1. The research design for this thesis based from Corbin and Strauss (2008). The figure is inspired by Austefjord and Opsahl (2020).

3.3 PARTICIPANTS

The sampling population (i.e., stakeholders within the Norwegian market for LIBs repurposing) chosen as participants in this study represents different actors in the Norwegian battery market for LIB. The research's initial desire for the sampling population was only stakeholders within the Norwegian market for repurposed LIB. This sampling population felt like the obvious choice with the research questions and -design. Furthermore, the study includes some actors that have not yet been able to get into the second-life LIB market. The inclusion of these companies and informants was not intended initially, but it became an interesting second angle for understanding the market – its incentives and strategic factors – during some interviews.

The participants (i.e., informants and companies) were accessed by direct contact over email or through the social media platform *LinkedIn*. The supervisors were also a crucial part of the initial access stage by giving pointers to which informants and companies should be contacted. Furthermore, during the interviews, there were, to some degree, used *snowballing*. In this technique, the interviewee recommends other potential informants or companies, which in turn leads to another recommendation (Myers & Newman, 2007; Wohlin, 2014).

Table 3.1 summarizes the different cases and informants used in this research's qualitative design choice. The table lists three different markets; (I) the market within ESS, (II) a market for aquatic mobility, and (III) a market for extending battery life through repairs. Moreover, the table lists all cases, what role the case has as a stakeholder in the larger market for battery business, which position the interviewee held at the time of contact, and lastly, a unique reference code.

Table 3.1. Case study interviews.

Market	Case	Stakeholder's role	Interviewees' position	Reference code
I	A	Energy storage / Second-life battery system provider	CEO	E-1
	B	Energy storage / Second-life battery system provider	R&D Associate	E-2
	B	Energy storage / Second-life battery system provider	Sales Associate	E-3
	C	Energy storage / Second-life battery system provider	CEO	E-4
	D	Energy storage / Second-life battery system provider	CINO	E-5
II	E	Waste reduction through extending battery life of micro-mobility units	CEO and Founder	X-1
III	F	Electrifying aquatic mobility	CEO and Founder	M-1

3.4 DATA GATHERING AND MATERIALS USED

Figure 3.1 shows the main data collection methods; interviews and literature review. For the interviews, selected informants (see Table 3.1) within the battery market were chosen. These informants represent businesses that are directly involved with forming solutions using LIBs. Semi-structured interviews were used to collect interview data (Kvale et al., 2009). The semi-structured interview allowed for asking elaboration and follow-up questions on topics of interest during the interview (Del Busso & Brottveit, 2018). Using semi-structured interviews also engages the participants neutrally, increases reliability, and reduces question bias (Babbie, 2010).

An interview guide with a questionnaire sheet (see Appendix A) was developed in advance of each interview. Although every interview was formed specifically for the company and topic researched, a standardized questionnaire sheet was used. The reason for this was in order to be able to map somewhat the same variables and allow for cross-case comparability (Miles et al., 2013). However, some companies were very unlike, and it was not appropriate to talk about all the topics covered in the questionnaire sheet. Therefore, there was a shift of focus during the interview for these particular cases to maximize the data gathering. Furthermore, the interviews with these particular cases transformed themselves from semi-structured interviews to unstructured interviews due to the questionnaire sheet being incomplete in some areas regarding the particular case. However, all the information gathered from the semi-structured and unstructured interviews gave valuable insight.

The information and data gathered through the interviews are considered the primary source of empirical data collection. In addition, supplementary data collected about the companies through channels such as their company website, official social media accounts, and other media coverage sources were also gathered. However, these supplementary data were used only to understand better the company itself, its business activities, resources, partners, channels, and customer segments.

As a secondary data source, the literature studies established theoretical understanding and insight into what has already been researched. All secondary data sources were structured in the reference program *Mendeley* in order to keep a good structure and overview of relevant sources. The process for gathering relevant literature was split into three: (1) Initial literature review, (2) Ongoing literature review, and lastly, (3) Final literature review. These three literature review processes, in combination with other processes, can be seen in Figure 3.1 and will be explained in the following three paragraphs.

Initial literature review. The initial literature review used theoretical and empirical studies to form a framework of what had already been researched to form and locate the research gap. The research problem was finally defined through an iterative process going back and forth between the research problem and literature.

Ongoing literature review. A simultaneous process with an ongoing literature review and case study research was conducted. Through the ongoing literature review, theoretical and empirical studies were used to build a study-based analysis of the phenomenon.

Final literature review. The output of this analytical process was then used as input for the discussion part and point of reference for our final literature review. The discussion process and the final literature review influenced each other, focusing on making the literature support our discussion topics.

3.5 ANALYSIS

As described in Section 3.4, secondary data were organized in Mendeley. In addition, color coding was used in Mendeley to provide a structure for the different annotations and markings.

Later, the most relevant secondary data sources as well as the primary data sources were gathered in *NVivo 12* for coding. The utilization of NVivo was, at the beginning of the project, considered too advanced to understand and learn. However, after seeing the width and amount of sources and data collected, a reassessment was made, and NVivo was used.

In NVivo, a set of nodes with sub-nodes were created using main topics, themes, and issues collected from the standard questionnaire sheet and relevant literature. The nodes and sub-nodes used are listed in Table 3.2. The nodes were chosen as the research unfolded itself during the data gathering stage. At this point, a clearer picture of where the research where headed was gained, making it natural to select the nodes and sub-nodes that provided the strongest relationship among the data. It should be noted that the empirical findings (from interviews) had the strongest influence on the choice of nodes. However, it was during the initial literature review that the main topics were first viewed, making the nodes indirectly stem from previous literature. This reference to the literature can be seen in sub-nodes 1.2 and 1.3, which have direct relevance to some of the key elements and components listed in Table 2.1.

As stated in the introduction, this thesis defines *strategic factors* as “Those activities a business needs to perform right to create value for its stakeholders: customers, shareholders, employees, suppliers, and other businesses.” Hence, the sub-nodes *Application*, *Key Partners*, and *Key Proposition* are seen highly relevant. Furthermore, the nodes *barriers* and *drivers* are directly linked to the second research question and its sub-questions, also making these relevant for the research.

Table 3.2. Overview of nodes and sub-nodes used for coding and identifying themes.

<table>
<tr><th>Main nodes</th><th colspan="3">Sub-nodes</th></tr>
<tr><td rowspan="10">1. Strategic factors</td><td rowspan="3">1.1. Application</td><td colspan="2">1.1.1. Energy Storage System</td></tr>
<tr><td colspan="2">1.1.2. Waste reduction through extending battery life of micro-mobility units</td></tr>
<tr><td colspan="2">1.1.3. Electrifying aquatic mobility</td></tr>
<tr><td rowspan="6">1.2. Key Partners</td><td rowspan="4">1.2.1. Battery collection</td><td>1.2.1.1. Insurance Companies</td></tr>
<tr><td>1.2.1.2. OEM</td></tr>
<tr><td>1.2.1.3. Waste Management</td></tr>
<tr><td>1.2.1.4. Other</td></tr>
<tr><td colspan="2">1.2.2. Investors</td></tr>
<tr><td colspan="2">1.2.3. Public Support System</td></tr>
<tr><td rowspan="2">1.3. Key Proposition</td><td colspan="2">1.3.1. New Batteries</td></tr>
<tr><td colspan="2">1.3.2. Repurposed Batteries</td></tr>
<tr><td rowspan="3">2. Barriers</td><td colspan="3">2.1. Lack of Communication and Collaberation</td></tr>
<tr><td colspan="3">2.2. Lack of Incentives</td></tr>
<tr><td colspan="3">2.3. Lack of Regulatory Standards</td></tr>
<tr><td rowspan="3">3. Drivers</td><td colspan="3">3.1. Communication and Collaberation</td></tr>
<tr><td colspan="3">3.2. Incentives</td></tr>
<tr><td colspan="3">3.3. Regulatory Standards</td></tr>
</table>

4 | ANALYSIS RESULTS

This chapter analyses and systematizes data obtained from interviews to understand what strategic factors, monetary incentives, and regulatory standards are identified in the Norwegian market for second-life battery utilization. The Cases presented in Table 3.1 are analyzed through a Within-Case analysis and a Cross-Case analysis. All data is obtained from interviews with employees from the respective companies and secondary data from company websites and media coverage.

4.1 WITHIN-CASE ANALYSIS

In this section, the different cases were separately analyzed by looking at the different companies through four main factors: *Key propositions*, *Collection of batteries*, *Incentives* and *Barriers for second-life battery utilization*. These main factors were identified as a common denominator for all cases and considered to have the greatest impact on companies' operations.

Cases A, B, C, and D are analyzed first as all being actors in the marked of ESS. Cases E and F have indirect links to the second-life battery market and are analyzed at the end of this section. Figure 4.1 illustrates their position of operation in the battery life cycle in order to create an overview of the various involvements along the chain.

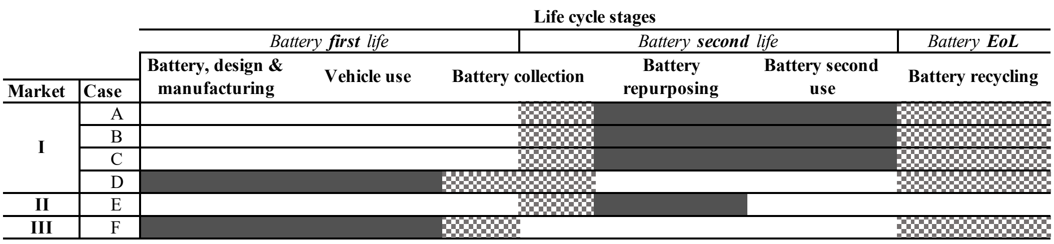


Figure 4.1. Comparison of the life cycle stages the different cases are involved in. Solid colors indicates a direct involvement in the life cycle sub-stage, while checkered colors indicates an indirect involvement.

4.1.1 Case A

Case A represents a company that manufactures BESSs with retired LIBs from EVs. Since 2020, their business idea has been to repurpose second-life batteries streamlined, safe, and cost-effective. In this way, they can maximize the value of EV batteries and accelerate a renewable future. Case A applies a data-driven approach to repurpose EVs batteries at a large scale to build BESSs.

Key propositions Case A mainly delivers residential energy storage solutions (e.g., a ESS with solar panel) and has developed digital technologies that allow an understanding of value and prognosis in terms of the viability of the batteries, as well as estimation of various operational parameters. "We see this as the only way to address a lot of the problems identified with batteries from EVs, in a sustainable manner." (Interviewee E-1). For Case A, the most viable way forward is to utilize battery modules rather than the battery pack or -cell. According to Interviewee E-1, this is due to the lack of standardized components used in a battery. Furthermore, some modules might be broken; hence the battery pack is not viable enough compared to the single module. The battery module, on the other hand, is easier to re-utilize.

Interviewee E-1 further explains Case A's activity which creates one of their key propositions: "We are developing a battery platform, or let us say, a product platform that allows us to plug in a lot of types of modules, and we utilize a lot of [different] types of modules regardless of the manufacturer, etc." (Interviewee E-1).

Collection of second-life batteries A key strategic decision in Case A is their collection of second-life batteries. "The logistics concerning sourcing second-life batteries is the number one contributor to cost" (Interviewee E-1). Therefore the company sources large volumes of batteries directly from the OEMs and does not engage with disassemblers. Those batteries are decommissioned from the OEM's EV models and collected. When Case A gets access to a battery pack, it is often no longer functioning. "The vast majority of batteries come out of first-life because there is a problem with them. So in order to reuse that pack, you have to repair it." (Interviewee E-1).

Incentives As for incentives, Case A receives governmental subsidization (i.e., financial aid through support schemes for companies that innovate in circularity) and the Enova stimulus package for a sustainable transition of energy use in the residential market.

Case A reveals a desire to receive more subsidizing of sustainable energy solutions for the residential sector. “An idea would be if you want to support the transition. If something is too expensive for people to make a conscious choice towards that direction, they only say they want sustainability, but when it comes to purchasing it, they will go for the cheapest in most cases. If the most sustainable solutions are also the cheapest, then you don’t have a problem”. (Interviewee E-1)

Barriers for second-life battery utilization A significant barrier identified in Case A is the ever-increasing number of batteries coming out of first life. The other is the variance of those batteries, “You’re dealing with a manufacturing problem when you don’t have a kind of standardization in terms of specifications” (Interviewee E-1). In addition, OEMs tend to be very reticent to selling modules and be associated with repurposers. “If you are a manufacturer (e.g., Volkswagen) and you sell a battery to a repurposer. If that battery catches fire, the manufacturer is likely to be held responsible in the media” (Interviewee E-1). They also find it challenging that the OEMs are restraining to sharing first-flight data, which implicates that “when you look at a module you don’t know if it’s been on the road for five years and done 100,000 kilometers or one year and 1,000 kilometers”.

Case A reveals specific regulatory gaps in the handling of retired batteries. E.g., when an insurance company takes ownership of a crashed EV, the vehicle is sold to the highest bidder, or in some cases, they have contracts with disassemblers. Very often, those disassemblers get the hold of EV batteries from insurance companies and junkyards. Unfortunately, the quality check done by these actors is not proper, potentially creating hazards when repurposers utilize these batteries in ESSs. The only objective is to get the most money from the retired batteries.

4.1.2 Case B

Case B represents a manufacturer of BESSs, delivering energy storage solutions to private households, as well as solar panels and associated equipment for optimal solar usability. With sustainability and CE as a main focus, the storage systems are build with second-life LIBs from EVs. Their strategic vision is to extend EV battery life cycle and reduce emissions per electric car produced. The company started in 2019, delivering ESS to cabins located off-grid. Today, many cabins are equipped with old solar panel systems supplying electricity for lighting. Case B recognized customers' interest in storing energy when they did not use their cabins, allowing them to arrive at the cabin with a fully loaded battery that could supply lighting and other electric applications.

Key propositions In Case B, BESS are manufactured in different dimensions, applicable for both private homes and cabins. In addition, custom-built solutions are provided by order, such as battery containers. These battery solutions aim to supplement solar panels, storing excess energy to perform peak-shaving and energy storage when the electricity costs are low. Furthermore, Case B's BESSs comes along with a software system, providing charging data and system status to the customer through a mobile application. This software solution also allows for better customer support.

Case B reveals that future products look to the construction industry. Many construction vehicles and machinery are set to be electrified in the coming years, creating a demand for vehicle charging at the construction site. Very often, construction sites take place off-grid. As a result, the necessity for mobile BESS solutions will increase, which is why the company in Case B sees this as a new proposition to expand its customer base.

Collection of second-life batteries As channels for the collection of second-life batteries, Case B performs sourcing of used EV batteries from car dismantlers and insurance companies. These batteries come mainly from vehicles unable to be used, typically wrecks or because of engine faults.

Incentives As a market-based incentive, a Norwegian bank is incorporated to support customers investing in energy storage solutions from this company. In addition, the so-called "Green loan" is supposed to provide one of the market's best terms and rates for closed mortgages and is working as an incentive to customers in Case B.

Further, the company interviewed in Case B does not receive any financial support from public policy systems. Instead, they would rather have investors and equipment suppliers identified as their key partners. The company has gained investors with considerable funding: "Our investors are important players. Their funding makes it possible for us to keep our products at a low cost in the beginning, as well as develop our technologies. We can then focus on delivering products to our customers" (Interviewee E-2). A strategic choice is to maintain a low price on products from the start, get to know the market, and create a solid customer base. Therefore, their relations with partners delivering additional equipment are crucial to delivering a good product at competitive prices.

"Today the Enova subsidizes up to 10.000NOK to households installing smart energy systems, but no funding is given for implementation of BESS" (Interviewee E-2). Case B suggests an alternative grid rental fee. While relieving the power grid, BESS users should be offered a lower fee, giving them the motivation to invest in such systems.

Barriers for second-life battery utilization The market's lack of standards and regulations is revealed in Case B as a barrier to second-life battery utilization. Without the government implementing standards, a large quantum of batteries goes straight to recycling, leaving a massive potential for energy storage. Case B states that with standards and regulations for second-life battery handling, they can have safe and constant access to batteries, making the business thrive further. A second barrier is the capacity of second-life batteries. In order to overcome this barrier, Case B has set a requirement of a minimum of 85% original capacity. If a battery is already purchased and tests show a capacity less than the limit, then the LIB cannot be included in products, only in demo products or research and testing that the company conducts.

4.1.3 Case C

The business investigated in Case C was founded 22 years ago, producing thermal solar collectors, waterborne underfloor heating systems, and heat pumps. Four years later, they started to deliver solar panel systems. In 2008 they developed an interest for LIBs, rebuilding old EVs that was initially equipped with acid lead batteries. This process gave a foundation that became valuable at a later stage when a new partnership started supplying the company with second-life batteries. Their knowledge made them able to repurpose these batteries in BESSs, which turned into a core business.

Key propositions The business in Case C delivers complete solar panel systems, integrated with a ESS built with repurposed EV batteries. Case C manufactures the energy storage solutions themselves, and an external manufacturer supplies the solar panels. Their leading customer group is cabin owners: "Typically, 90-95% of sales are represented by delivering such systems to cabins off-grid" (Interviewee E-4). However, in recent years, the company has experienced an increase in requests for installing such systems in households, which has increased business.

Collection of second-life batteries Case C reveals a partnership with a battery collector to supply second-life batteries. This partnership ensures a steady flow of batteries, as long as there is availability from the collector, eliminating uncertainty in supply. All batteries provided by the dismantler have been clarified regarding capacity and safety. In addition, the company has engaged in another partnership with a second-life battery provider. This partnership will increase their access to batteries, creating the potential to grow the company.

Incentives The business described in Case C has made several strategic decisions over the last 22 years, such as changing its main products and adapting to new markets. "We have worked ourselves up gradually, step by step" (Interviewee E-4). Their technical knowledge has been essential when exploring new products. In addition, they have managed to get a CE marking[1] on their solutions, which many

[1] CE marking refers to a product that have been "[...] assessed to meet high safety, health, and environmental protection requirements" (European Commission, n.d.)

of the competitors do not have. The company's ability to deliver products that satisfy customer needs means no public policy system or external investors have been involved. As for funding, they have been selling diesel forklifts up until last year to fund the development and establishment of their BESSs.

Barriers for second-life battery utilization Although Case C reveals two suppliers of second-life batteries, they see the possibility of increasing their amount of utilization in ESSs. A barrier identified is that a remarkable amount of batteries collected by second-life battery providers cannot be reused due to terms from the manufacturer and goes straight to recycling. They also have to remove labels from the batteries that they receive because the OEM does not want to be connected with eventual technical faults or hazards that the battery might cause during reuse in other applications. As other interviewees have declared, the ecosystem for collection of spent EV batteries, and channels for supply, is limited. In addition, economic incentives such as the EV- and solar panel market have, is missing when investing in second-life applications.

4.1.4 Case D

The business represented in Case D was created to retain a specially composed team with competence within battery-based ESSs and pursue developed products and services from the previous business. Its area of business arose from telecommunication, but today Case D design and manufacture market smart energy storage solutions (e.g., ESSs) to contribute to clean, cost-effective and reliable electricity to customers.

Key propositions The primary focus of the business in Case D is ESSs. Typically they manufacture ESSs the in the range from 3kW to 1MW, giving products the ability to be modular and scalable for commercial and industrial facilities, agriculture, EV charging and distribution system operators. Case D has chosen not to fully enter the second-life battery market as they currently wish to first succeed as a provider of ESSs. Instead, their decision from the beginning was to initiate production and sales of BESS with first-life batteries, giving them a foothold in the energy storage market without needing to handle the uncertainty related to second-life batteries.

Collection of batteries In Case D, the procurement of batteries happens directly from the OEM. As mentioned, only first-life batteries are utilized in ESS in this case. The only exception is when the company has participated in pilot projects on second-life battery energy storage solutions. In addition, the battery provider has typically been an authorized battery waste management company.

Incentives Case D identifies the Norwegian Research Council, Innovation Norway, and Enova as stakeholders. In addition, the ESS provider states that, soon, investors will be essential for the further growth of the company.

Barriers for second-life battery utilization Case D does not repurpose second-life LIBs in their BESSs. "In principle, there is no major difference between the batteries being new or reused in terms of application. The only variation is uncertainty related to capacity and safety. So, in the end, it boils down to an issue of costs" (Interviewee E-5). Their main barrier to the utilization of second-life batteries has been cost-efficiency. Their solutions with first-life batteries have had great sales, and they state that there is no indication that this will change. Only pilot projects on BESS with repurposed EV batteries have been conducted in cooperation with other actors. Case D sees this as a technology that is not profitable today but will be in the future. The interviewee explains that in a product they provide, an energy storage cabinet to relieve the grid can principally be equipped with second-life batteries as long as it can communicate with the BMS.

Another barrier that is making concerns in Case D in terms of utilization of second-life batteries in their ESSs, is the lack of safety. "Basically, we would be careful placing spent batteries close to people, in case of hazards" (Interviewee E-5). In addition, the availability of second-life batteries is too poor. Therefore, Case D identifies a missing ecosystem, providing a collection of retired batteries from EVs and channels for supply. The system could also relieve uncertainty related to producer responsibility for OEMs. The interviewee explains that they would gladly participate in such a system to get it industrialized and available for the market.

4.1.5 Case E

Case E represents a repairing company using second-life batteries to power a wide range of smaller applications. Their specialty is to reconstruct battery cells for utilization in various applications. The business model identified in Case E utilizes cells available, which typically have been micro-mobility batteries from electric bicycles and scooters. Their business also includes specialized tasks, i.e., if someone has a used battery cell, the company collects it and reconstructs it with a brand new cell. For Norwegian customers, the company has identified that it is cheaper to repair batteries in Norway than outsourcing to foreign countries, e.g., Poland or China, because of shipping costs related to traffic safety and regulations.

Key proposition The key proposition in Case E is their skills and knowledge to reconstruct destroyed cells to extend the life cycle to batteries that would otherwise go straight to recycling. In addition, they focus on designing for reliability to make their products last. “If we manage to make a solution that will not break during its lifetime, we consider it a success. That’s most important for us from a sustainable point of view” (Interviewee X-1). They build the batteries pretty much in the same way as the prominent manufacturers, giving the same possibilities regarding recycling at EoL. At EoL, micro-mobility batteries are ground into small pieces before separating materials through different recycling processes. Hence, the components are not disassembled, and it is more sustainable if the company in Case E redesigns them to be reused rather than having them go to recycling. In addition, they give a new life to the application. “If we build a new battery for a bicycle that you cannot buy a battery for, then we’ve saved your bicycle from being recycled” (Interviewee X-1).

The business in Case has earlier used second-life batteries from EVs to build a storage solution for a camper van. In terms of micro-mobility batteries, reconstructed battery modules were used to expand the life of electric forklifts.

Collection of batteries For Case E, the used batteries are typically sourced from electric scooter operators in larger cities. Operators consider these battery cells useless, resulting in a relatively low cost, sometimes free. “Essentially, it means we have access to battery cells for a good price” (Interviewee X-1). The more prominent focus on EV batteries means that few actors are interested in micro-mobility batteries. However, these battery packs are typically smaller than the ones found in EVs, which results in a time-consuming operation if they are to be reassembled as larger battery packs.

Incentives Regarding financial support, Case E is receiving a commercialization grant from Innovation Norway. In addition, they are in talks with a university for a research project, which includes funding. However, beyond this, no funding is ensured. Therefore, Case E desires the government to subsidize battery cell repairers to facilitate further growth. Furthermore, the government has implemented incentives for customers to choose EVs over fossil-fueled vehicles. However, this is only for the battery's first life. Therefore, the company in Case E desires consideration of subsidizing repair and second-life batteries.

Barriers for second-life battery utilization An identified barrier is the lack of cooperation with battery OEMs. One point is that to get access to second-life batteries from manufacturers; they need to engage in a deal, which is highly difficult to get from a niche company. Because of the producer responsibility that the manufacturer has, they cannot be sure that Case E can ensure safety and reliability when using their batteries in various energy storage applications. In addition, there is a desire for cooperation with OEMs to access all damaged batteries, which are usable for redesign as new cells. A lot of OEMs sends damaged batteries to recycling, which Case E could use in their products, extending the battery life. Another barrier appears when repairing batteries. The lack of support from OEMs makes it challenging to supply parts. When in need of replacement parts, Case E has to manufacture the parts themselves. Having to self manufacture the components pushes the price, which has an upper limit equal to the price of new cells.

In the electric scooter business, many of the biggest operators have encrypted the battery and the battery host system, meaning the battery management system cannot be disassembled without compromising the battery cells.

4.1.6 Case F

The company researched in Case F is a manufacturer of electric boats. They started their business by electrifying old combustion-engine boats. Today, they are also designing and selling fully electric boats. The business model discovered in Case F focuses on technology development. With two own designed boats, they aim to show their technical competency on the market. Their technological knowledge reaches through the whole product, from the rotor to the engine and the boat itself. In recent years, they have specialized more and more in software systems, including Battery management systems.

Key proposition Although Case F has started designing fully electric boats, today's key proposition is still the electrification of combustion engine-powered boats. This proposition is their core business, but the interest in their fully electric boats is increasing, making this a potential core business for the future. In this design, the customer will find a boat equipped with a lot of the same equipment found in an EV to give much of the same comfortable feeling. They also price boats on the same level as fossil-fueled models. The main focus in Case F is to promote their technologies within electric boat equipment through the newly designed boats.

Collection of batteries In Case F, the procurement of LIBs happens from a OEM in Asia, delivering LFP batteries known for good safety and reliability. When the battery pack is decommissioned from one of Case F's boats, it goes to a contracted battery collector. The battery collector can investigate if the battery is fit for reuse in a second-life application for a repurposer or if it needs to be sent directly to recycling.

Stakeholders Case F was partly invested in by a governmental institution, providing funds for their research and development and the production of electric boats. In addition, Case F has received funding from Innovation Norway.

Barriers for second-life battery utilization Case F does not reuse second-life batteries in its products. At the moment, the choice to repurpose electric car batteries in boats will be too costly. Furthermore, the market for electric boats is relatively new and not as developed in terms of policies and regulations as the Norwegian EV market. “Nothing is written in stone, so no common standard has been developed for actors in the electric boat market” (Interviewee M-1). Case F identifies the lack of subsidizing for Electric boats, as the tax cut users of EV receive. In addition, the interviewee wants harbors to support electric boats by giving users goods, such as priority docks and free charging.

4.2 CROSS-CASE ANALYSIS

This section presents a cross-case analysis, investigating patterns, resemblances, and dissimilarities among the cases, in order to highlight the topics that were shown to be prominent in Section 4.1. The collection of data from the Norwegian second-life battery market has been mapped through qualitative interviews, with the presented research questions from Section 1.2 in mind. This Cross-case analysis is divided into subsections; strategic factors (Section 4.2.1), monetary incentives (Section 4.2.2) and regulatory standards (Section 4.2.3).

4.2.1 Strategic factors

A variety of strategic factors was identified in the interviews. This section presents those strategic factors identified as having the greatest impact on Cases A-F's business. The strategic factors presented are *Collection of batteries*, *Use case for batteries*, *Customer segments*, and *Stakeholders*.

Collection of batteries A varied selection of channels for battery collection have been identified. Table 4.1 lists the diversity of channels identified for companies in all cases.

Table 4.1. Identified channels for battery collection.

Case	Main Battery Provider	Battery state
A	OEM	EoL EV batteries
B	Car dismantlers and insurance companies	EoL EV batteries
C	Battery collector	EoL EV batteries
D	OEM	New batteries
E	Electric scooter operators	EoL micro mobility batteries
F	OEM	New batteries

Use case of batteries Use case for LIBs varies between all cases investigated. Cases A-D can be highlighted in terms of utilization of LIBs in ESSs. Although Cases D and F do not focus their core business around second-life batteries, they are still drawn into this analysis because of their potential for utilization. Table 4.2 lists the diversity in core business in Cases A-F, in terms of LIB utilization.

Table 4.2. Use case of LIBs in Cases A-F.

Case	Battery life cycle stage	Core business	Other business
A	Second-life batteries	Residential ESSs	Industrial ESSs
B	Second-life batteries	ESSs for residents and off-grid cabins	Custom built energy storage solutions for industrial purposes
C	Second-life batteries	Solar Panel Systems with integrated ESSs for cabins off-grid	Residential Solar Panel Systems
D	First-life batteries	ESSs for commercial and industrial purpose, agriculture, EV charging and Distribution System Operators	Second-life ESSs (Pilot Projects)
E	Second-life mobility batteries	Reconstructing battery cells for various applications	ESSs by customer order
F	First-life batteries	Electrifying combustion engine boats	Design of electric boats with focus on technology development

Customer segments The cases identify a variety of customer segments. Cases A, B, D, and E deliver services or solutions other businesses use in their service or as a part of a bigger product or solution. Through the delivery of ESSs for industrial purposes (Cases A, B, and D) or reconstructing battery cells for electric scooter operators (Case E), a Business to Business (B2B) sales method is applied. Case A also provides other businesses, as presented in Table 4.2, with ESSs. In addition, Cases A, B, and E also practices a Business to Consumer (B2C) method. This method is also identified in Cases C and F, all delivering services or solutions to consumers. Such solutions or services include electric boats, special customer orders, or residential energy storage solutions.

Stakeholders Various stakeholders in the second-life battery market are identified in the investigated cases. They are involved as investors, businesses, suppliers, or national support programs. While some cases rely heavily on their investors and partners, others operate relatively independently and identify with few stakeholders. Table 4.3 lists the stakeholders identified by Cases A-F, categorized by their function of interest from a case perspective.

Table 4.3. Stakeholders identified in Cases A-F, categorized by their function.

Stakeholders		Case
Investors	Shareholders	B, C, D*, E, F*
	Venture capital	A
	Private Equity funds	A
	County municipality	F*
Businesses	OEMs	A
	Battery collectors	C
	Battery recyclers	A, B, C, D*, F*
	Insurance companies	B
	Car dismantlers	B
	Distribution System Operators	D*
Suppliers	Component suppliers	B, C, D*
	Ad-on suppliers (e.g., solar panels)	B, C
National support	Start-up financing (e.g., Innovation Norway)	A, D*, E, F*
	R&D financing (e.g., Enova)	A, D*

* Specifies that the case uses first-life batteries.

4.2.2 Monetary incentives

A handful of monetary incentives were identified for the cases in the market for second-life battery applications. There are possibilities for financial support from governmental institutions when providing green energy solutions. Cases A, D, E, and F benefit from this support, listing Innovation Norway as the common financial supporter.

4.2.3 Regulatory standards

The market for secondary battery applications has a poor adoption of regulatory standards. Data obtained and analyzed from case interviews shows a lack of regulatory standards. First of all, there is a need for management of the increased EoL batteries. Secondly, a specified marked structure is missing: Governmental interference is desired by the actors to develop business policies and standardization for actors in the second-life battery application marked. Finally, a cooperative relationship with OEMs is mentioned by a majority of interviewees. However, a relationship between these two actors is rare. Only Case A has managed to obtain such and, therefore, can procure second-life batteries from an OEM.

4.2.4 Case overview

Table 4.4 provides an overview of the cases relevant for the different nodes and sub-nodes. Furthermore, Table 4.4 provides a summary of this section, whereas the reason for one case being grouped in a specified sub-node has been addressed earlier in this chapter.

Table 4.4. Summary of the empirical findings as coded nodes for the relevant cases.

Main nodes	Sub-nodes			Case
1. Strategic factors	1.1. Application	1.1.1. Energy Storage System		A, B, C, D*
		1.1.2. Waste reduction through extending battery life of micro-mobility units		E
		1.1.3. Electrifying aquatic mobility		F*
	1.2. Key Partners	1.2.1. Battery collection	1.2.1.1. Insurance Companies	B
			1.2.1.2. OEM	A, D*, F*
			1.2.1.3. Waste Management	B, C, E
			1.2.1.4. Other	E
		1.2.2. Investors		A, B, D*, E, F*
		1.2.3. Public Support System		A, B, D*, E, F*
	1.3. Key Proposition	1.3.1. New Batteries		D*, F*
		1.3.2. Repurposed Batteries		A, B, C, E
2. Barriers	2.1. Lack of Communication and Collaberation			A, B, C, D*, E
	2.2. Lack of Incentives			A, B, C, D*, E, F*
	2.3. Lack of Regulatory Standards			A, B, C, D*, E, F*
3. Drivers	3.1. Communication and Collaberation			C
	3.2. Incentives			B, D*
	3.3. Regulatory Standards			D*

* Specifies that the case uses first-life batteries.

5 | DISCUSSION

Our findings have mapped similarities and differences across the cases regarding strategic factors, incentives, and regulatory standards in the Norwegian second-life battery repurposing market. In this chapter, these findings will be discussed in relation to the existing theory within the field of second-life battery repurposing. First, as the cases investigated are in a relatively new business area, there have been identified three key strategic factors which focus on having (1) a fundamental vision for their business, (2) a reliable sourcing of second-life batteries, and (3) a well-functioning application. Secondly, the lack of government subsidizing and support in areas that come after the battery's first life (i.e., after a battery has been used in a EV) makes it difficult for companies to establish a sustainable business. Third, a non-existent degree of collaboration in the repurposing market restrains the optimal circular battery value chain. Following this discussion, the thesis' contribution will be discussed.

5.1 STRATEGIC FACTORS FOR SECOND-LIFE BATTERY REPURPOSERS

Empirical evidence shows a pattern of strategic factors within the investigated cases. The importance of having a secure supply chain and a viable product has proven to be essential for the business of battery repurposing. Hence, this section addresses and discusses the most significant factors impacting the individual cases' operations. These are sourcing of second-life batteries and use case for second-life batteries.

5.1.1 Strategic factors that can provide success

According to the litterateur (i.e., Jiao, 2017; Jiao & Evans, 2018; Johnson et al., 2008; Morse, 1991; Osterwalder & Pigneur, 2010; J. E. Richardson, 2005), several factors plays in when a business model is to be formed. Furthermore, as Casadesus-Masanell and Ricart (2010) introduces, the strategic stage includes choosing a plan for which business model to adopt. Hence, the chosen business model should recognize the strategic factors to be evaluated. As the empirical evidence gathered in this thesis shows, not all businesses have a clear vision for their chosen business model, which again influences the strategic factors that the business will associate itself with.

Neglecting strategic factors can cause diversion. With Case C's organic growth, we see Casadesus-Masanell and Ricart (2010) notion regarding their integrated framework of strategy, business model, and tactics. Case C has been in the repurposing market since 2008 and, on multiple occasions, has seen the need for redesigning its business model in order for them to reach its goals. However, this has not been a focus for Case C as they state that "I can't say that we have mapped it [the business model and strategy] in a good way. It hasn't been that important since it [the company] was created over time. It started with interest, and then it just built up from there." (Interviewee E-4). However, Case C has seen relatively slow growth in their business for repurposing second-life batteries, so they started selling combustion engine-powered forklifts, which somewhat diverted their sustainable vision. This diversion might be due to several factors: (1) the lack of focus on building a fundamental strategy and business, (2) little to no inclusion with national or regional support programs (i.e., Innovation Norway and Enova), and (3) unwillingness to open up for and gather investors.

5.1.2 Sourcing of second-life batteries

Channels for second-life battery sourcing have proven to be a vital strategic factor for second-life battery repurposers. Section 4.2.1 shows that companies have utilized different channels for supply. Although they all source second-life batteries, some factors may vary between the channels, which will be addressed and discussed in more detail.

Pereira et al. (2014) considers risk evaluation, related to the number of suppliers, as a priority for procurement selection. The amount of battery suppliers in the Norwegian repurposing market is increasing. However, the current availability of sources of second-life batteries is few. The analysis shows that repurposers operate with few battery suppliers. Pereira et al. (2014) addresses the importance of having a diversity of suppliers in order to ensure a safe and stable supply. Both Case B and C source their batteries from Norwegian suppliers. As stated in the analysis (Section 4.1), Case B has an agreement with car dismantlers and insurance companies, while Case C has a partnership with a battery collector. Case C further reveals a potential future partnership with another battery collector, increasing their diversity of suppliers. Hence, Cases B and C collect their batteries from the only possible channels located in Norway. As the number of suppliers identified in the Norwegian repurposing market is few, this can relate to a diversity risk which further results in a vulnerable supply chain, as stated by Pereira et al. (2014).

Case A sources batteries directly from an OEM. In comparison to other companies that source from car dismantlers and insurance companies, they considered these batteries safer for repurposing since the OEM have examined the batteries themselves. On the other hand, it should be more important to address the environmental segment when selecting suppliers. Klumpp (2018) describes the environmental segment as a concern of capital importance. OEMs are located abroad, and the ecological footprint of sourcing batteries will be higher than sourcing from Norwegian battery collectors or insurance companies. In addition, the repurposer has to take transportation costs into account, as Idjis and da Costa (2017) explains transportation costs as one of the main components when calculating repurpose profitability.

5.1.3 Use case for second-life batteries

With all cases analyzed, it appears that the use case for second-life batteries can be recognized as an important strategic factor. The utilization of second-life batteries does not vary significantly between the cases. All providers have centered their core business around delivering ESS for residential-, industrial- or grid purposes. One can discuss the most successful application for the use case, but all seem to have succeeded in creating a good customer base for their solutions.

Empirical data reveals that residential ESSs are exclusively connected for the purpose of storing energy from renewable energy resources. This use case gives a sustainable ecological footprint which would differ if the system stored energy from fossil fuels

(Kalair et al., 2021). Furthermore, Hua et al. (2020) states that second-life batteries can also be used in industrial vehicles, e.g., forklifts, such as Case E has done with second-life micro-mobility batteries from electric scooters. This opportunity can create a potential additional second-life use case, given that the EoL batteries from the electric scooters are collected and managed correctly.

Market trends for second-life reuse and recycling for EV batteries, are reviewed by Zhao et al. (2021). Findings show that the use of ESSs in connection to electric grids will be one of the main drivers of increased global battery demand. As identified by Case E, there is already a demand for ESSs connected to the Norwegian grid. "ESSs can relieve the load on the grid when electricity consumption increases without having to expand the national grid" (Interviewee X-1). From an environmental point of view, it will be important to utilize the leftover storage capacity in second-life batteries when the demand for ESSs increases. Employing new batteries in grid ESS will only cause increased demand for scarce raw materials (Olsson et al., 2018).

Hossain et al. (2020) identifies solar power as the most prominent energy contributor globally by 2040, surpassing gas and coal. In addition, wind and other renewable energy resources will continue to increase, making the overall share of energy generated from renewable energy resources improve from 26% to 41% (Hossain et al., 2020). Already countable for connecting to solar panel (Warner, 2015), utilizing ESSs could generate further business opportunities by connecting to renewable energy resources such as wind turbines, hydro plants, as well as storing energy on offshore installations (Hemmati, 2018; Pavković et al., 2016; Y. Yang et al., 2018).

5.2 DRIVERS AND BARRIERS IN THE SECOND-LIFE BATTERY MARKET

The market for second-life battery utilization reveals drivers and barriers in various aspects. Drivers in this market tend to appear from intrinsic motivation, while barriers are typically a product of a missing market structure. This section addresses and discusses drivers and barriers and highlights the possibility that driver, for one case, can be a barrier for another, and vice versa.

5.2.1 Barriers for second-life battery utilization

However, how beneficial the usage of second-life batteries is, several significant barriers were identified through qualitative interviews. Jiao (2017, pp. 162–163) lists critical challenges of implementing second-life battery use. These challenges are identical to the barriers identified in Cases A-F. In order to make second-life applications more promising, the market has to consider and overcome the recognized obstacles. Table 5.1 lists those barriers identified in Cases A-F as well as by Jiao (2017, pp. 162–163). The suggested solutions are findings gained from the informants and are actions to which the whole market has to contribute, including governmental institutions.

Table 5.1. Barriers for second-life battery utilization with suggested solutions.

Barriers	**Suggested solutions**	**Cases**
Increased EoL batteries	Better battery management	A, B, C, D*, E*
Variance in battery technology	Standardization for reuse purposes	A, B, C, E
Cost-efficiency	Incentives and financial support	D*
OEM responsibility	Cooperation between OEMs and Second-life battery business	B, C
Lack of raw materials	Correct waste management/Collection of spent batteries	A, B, C, E
Lack of public interest	Organizing education, seminars, pilot projects	B, D*, E
Lack in battery technology	Investing in research and development	A, B, C, D*, E, F*
Lack of market structure	Invest in marked development	A, B, C, D*
Lack of business policy and standardization	Develop organizational and governmental policies	A, B, C, D*, E, F*
Securing supply and distributing chain	Analysis of market and supply chain	A, B, C, E

* Specifies that the case uses first-life batteries.

Several cases reported a non-existing collaboration and information flow between themselves and the OEM, resulting in a need-to-know situation with low effort in developing solutions across businesses and value stages with "the greater good" in mind. Furthermore, several cases agree that batteries developed for first-life EV utilization lack a design for enabling second-life utilization. Finally, even though researchers have called for increased battery standards and certifications (i.e., Hu et al., 2017; Reinhardt et al., 2019), there is still a lack a mandatory and widespread regulation of such.

Several advantages can be reached by developing an overall system or platform to involve all actors related to second-life battery utilization in the battery life cycle. OEMs, car producers, insurance companies, battery collectors, junkyards, and battery repurposers can all benefit from such an organized market. Such a system can ensure better management of EoL batteries, guaranteeing that a more significant quantity is utilized in second-life applications, eliminating waste of potential energy resources (Olsson et al., 2018). It can also give fertile ground for a marked only including serious actors with proper qualifications to handle used batteries.

The process of controlling and mapping a battery's characteristics, as seen in Figure 2.3, can be systematized to release battery repurposers of this task. Such a process can be complex for most repurposers, and it will give a better overview of how many second-life batteries are available for utilization if performed by, e.g., a governmental actor (Warner, 2015). Firms can then procure more significant amounts. It can be challenging to motivate the whole battery value chain to be part of such a system. Several larger and smaller actors are involved with their interests and limits, meaning that a regulative framework might be the solution to ensure such a system. Such an overall system can be an advantage for the battery value chain in its entirety and can contribute to environmental benefits for society. It will be essential to develop a regulatory framework in order to have the ability to control the outcome for EoL batteries when they are no longer helpful for their first-life purpose in EVs. A comprehensible regulative framework can ensure that EV batteries available for repurposing are utilized even better before being recycled (Engel et al., 2019; Faessler, 2021; Jiao & Evans, 2018; Zhao et al., 2021).

A non-existent degree of collaboration

In regards to the schematic typology model (see Figure 2.7) of Jiao and Evans (2018), our findings shows a different practice. First, it should be noted that the study of Jiao and Evans (2018) only viewed second-life battery solution providers, while our findings include some first-life battery solution providers as well. Hence, only Cases A, B, C, and E will be directly relevant for this discussion as these are the cases dealing with second-life battery solutions.

Our findings show that only one of the cases, Case A, utilizes a business model that includes the OEM. The business model for Case A is typologically oriented within the categorization called *Standard Business Model* in Figure 2.7. For the remaining cases, they do not have an explicit link to the OEM – neither for supply nor collaboration. However, by replacing the "OEM" with the "Battery Collector"[1] one will be able to include the other cases in the figure as well. With such an altering of the original schematic typology of business models for second-life battery repurposing (see Figure 2.7), all cases within the second-life battery market (i.e., Cases A, B, C, E) can be placed within the first business model type – standard business model – as illustrated by Figure 5.1. Hence, there is no form of collaboration from the battery collector to the second-life battery solution provider or from the second-life battery solution provider to the end customer. The battery collector acts only as a supplier, and a collaboration line is non-existent, neither from the supplier nor the buyer. Figure 5.1 illustrate the schematic typology overview and show great differences to the original findings from Jiao (2017) and Jiao and Evans (2018) as seen in Figure 2.7. The figure also illustrates which life-cycle stages and sub-stages the different processes are involved in and are highlighted in white. The gray stages are stages that come in before or after and are included only to provide the whole overview.

[1] "Battery Collector" is here used as a common name for the player that comes in before the second-life battery repurposer.

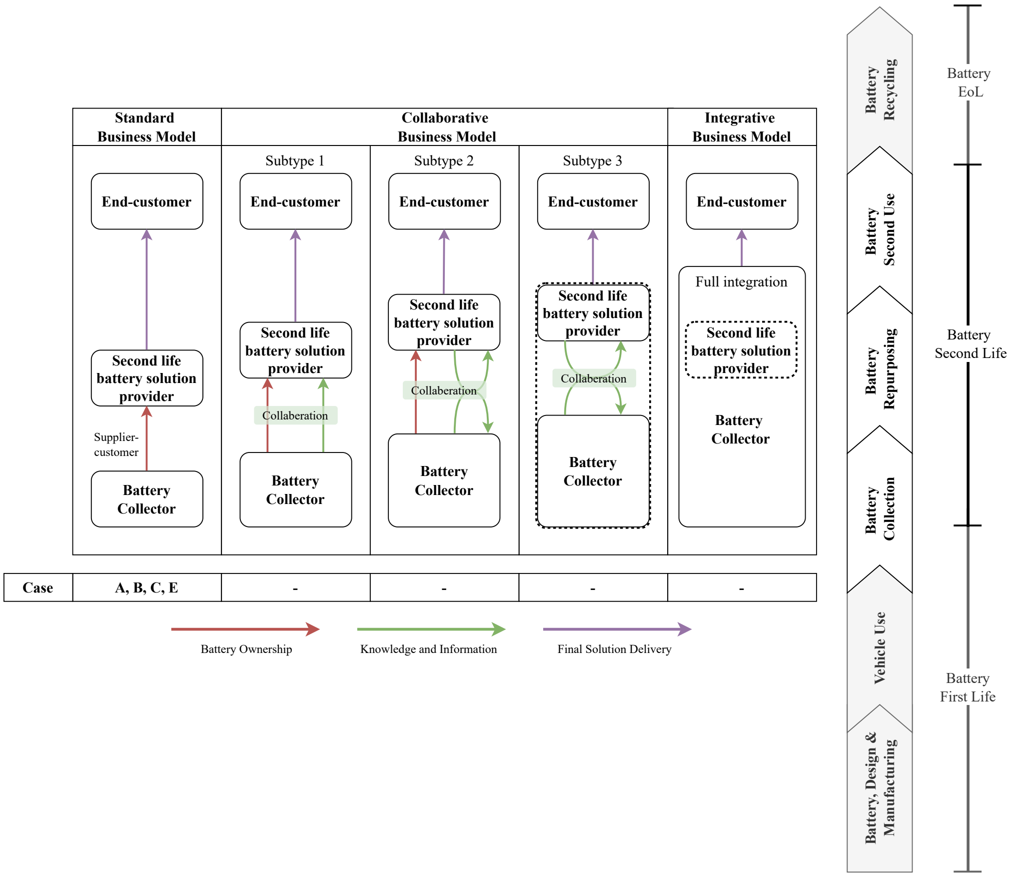


Figure 5.1. A schematic typology overview for the used business models for cases in the Norwegian market for second-life battery repurposing. Figure adapted from Jiao (2017, pp. 173, 189) and Jiao and Evans (2018, pp. 327, 336).

5.2.2 A rapid increase in EoL batteries

Incentives for battery EVs made Norway a global leader in introducing EVs (Ingeborgrud & Ryghaug, 2019). As mentioned in Chapter 1, a rapid increase in EoL batteries from EVs on the Norwegian market is happening and will continue to grow. It can be discussed if this is a driver or a barrier for repurposers of second-life batteries. For cases investigated in Chapter 4, a large quantity of EoL batteries might not always mean increased supply to the repurposer.

The increase in EoL batteries seen as a barrier. As the findings from Case A's collection of batteries show, the vast majority of the battery packs they access needs repairs. As shown in Figure 2.3, several crucial activities have to be ensured in order to successfully employ EoL batteries in second-life applications. These crucial activities are demanding processes that should be performed with accuracy to ensure safety and viability for the product (Warner, 2015). Moreover, as this process is vital in the battery's further life-cycle stage, it might not be best practice for a company to endeavor on these activities themselves without the correct competence and knowledge.

The increase in EoL batteries seen as a driver. With an increase in the battery supply and where a company does not possess the necessary resources, it opens up for a battery ecosystem that incorporates companies, such as the one in Case E, as an outsourcing possibility for the testing and re-assembly activities illustrated in Figure 2.3. Therefore, such an ecosystem can be viewed as a beneficial solution for companies that finds themselves in a situation where the increase in EoL batteries is seen as a barrier, as stated in the previous paragraph. Furthermore, an increase in the battery supply can work as an incentive, allowing growing companies to deliver more and better second-life solutions to customers. However, it depends on having a well-functioned system for battery collection and preparation processes for repurposing. Moreover, having the correct competence and knowledge internally in the company is a necessity. Case B and C are both examples of such companies. In addition, case C has even been approved for CE marking[2] of their products, indicating that they possess good knowledge and expertise in the field.

EC's proposition for governing EoL batteries. The EC's proposal suggests a labeling system for LIBs in order to increase traceability and transparency throughout the battery value chain. An electronic exchange system and a passport for each battery are suggested, containing information about a battery's characteristics and use. Such a system can provide sufficient battery information to repurposers and stimulate the second-life battery market. The proposal also highlights the ambitious solution of implementing mandatory second life readiness, forcing OEMs to design for optimal repurposing (European Commission, 2020).

[2] CE marking refers to a product that have been "[...] assessed to meet high safety, health, and environmental protection requirements" (European Commission, n.d.)

5.3 CONTRIBUTIONS

The research's primary outcome is a linkage between the Norwegian market for second-life battery repurposing and previously contributed theoretical frameworks and findings. Furthermore, the findings show different aspects of the business models in the respective market compared to the current literature, as none of the analyzed cases can be identified with having a communication or collaboration with their battery collector.

Strategic factors. The empirical evidence highlights key strategic factors that a business should consider when constructing its business model. For example, it is found that businesses within the second-life battery repurposing market should give focus to their use case and collection as these are found to be significantly impacting their operations. Furthermore, stakeholders have been viewed as a contributing strategic factor which, in correlation to use case and collection, can be beneficial for overcoming barriers in the market, such as allowing the business to, e.g., have a steady flow of second-life batteries.

Business models and collaboration. Interestingly, none of the cases can be placed in the schematic topology sub-types other than a standardized business model. Hence, where previous literature found some degree of collaboration between the OEM and the second-life battery repurposer, our findings illustrate zero extent of such a collaboration. The differences from the previous literature might be due to this study's cases mainly consisting of emerging stakeholders (e.g., start-ups) in the second-life battery market.

Barriers. The empirical evidence in this study and previous theories highlight several barriers in today's second-life battery repurposing market. Within the Norwegian context, most barriers occur because of a lack of market structure and national regulatory standards.

Drivers. Some cases find monetary incentives and regulatory standards a barrier, while others thrive on them, making them more drivers than barriers. Therefore, this research cannot conclude on a single element as a driver or a barrier but rather highlight the importance of bringing sets of regulatory standards to the table to make the market equal for all actors and stakeholders.

Moreover, a couple of cases gave a fascinating insight into why they have not endorsed second-life battery utilization today. With the market price of new batteries being favorable regarding costs and liability, potential second-life battery repurposers choose not to enter this market. Instead, they view the second-life battery repurposing market as an exciting and sustainable way forward if it is to be accommodated. Hence, governmental facilitation can be a decisive catalyst for expanding the second-life battery repurposing market.

6 | CONCLUSION

In this thesis, six cases have been investigated and analyzed through a qualitative multiple case study to map critical strategic factors, monetary incentives, and regulatory standards for actors in the Norwegian second-life battery repurpose market.

The qualitative multi-case design allowed for an in-depth insight into most actors within the Norwegian second-life battery repurposing market while also enabling the thesis to include relevant and essential literature on the field. The theoretical framework used in this thesis illustrates the novice and untouched research area today, yielding an increased focus on said area to gain better insight into the rising second-life battery repurposing market. It is perceived that by raising awareness of today's market, businesses and researchers will illuminate the way forward and contribute to the societal importance of sustainability.

Our empirical evidence mapped out what strategic factors need to be highlighted and identified what monetary incentives and set of regulatory standards have affected, and can affect, businesses in the Norwegian second-life battery repurposing market.

6.1 LIMITATIONS

Several internal and external limitations have limited the potential outcomes and affected the results throughout this research. In this section, three main limitations will be discussed regarding how the separate limitation has affected the result and what could have been if the respective limitation had not been raised. First, a lack of stakeholders in the second-life LIBs market in general, as well as even fewer candidates willing to be a part of this study, has limited valuable information gathering. Moreover, the study has limited itself by focusing only on the Norwegian market for repurposing of second-life LIBs. Secondly, some companies have viewed business strategies and strategic choices as confidential. Therefore, it has been a limitation in getting precise business strategies. Lastly, the rapid development of both the technological and business aspect in regards to second-life LIBs have limited the direct relevance of earlier studies.

Lack of stakeholders Throughout this study, there has been an issue with gathering enough interview objects that could provide viable and relevant information on the topic of study. Such a limitation is because businesses within the repurposing of second-life LIBs are new, and the players in the market within Norway are few. As a possibility, the research could have broadened its geographical choice to be studied. However, that would have done a different project. Therefore, it is instead recommended and encouraged for further research that expands the geographical limitation to quantify the stakeholders to a greater extent than this study has.

6.2 FUTURE RESEARCH

Future research is recommended to make the market for second-life batteries thrive. This Master's study builds on currently available research, where further research corresponds with barriers presented by the thesis's empirical evidence. Hence, no changes have been made to overcome the barriers previously identified by the literature, which may have limited the potential development of the market. In addition, future research is recommended to focus more in-depth on how governmental institutions can apply tools, such as incentives and regulatory standards, to create drivers for second-life battery utilization.

Having compared the cases' business models to the proposed schematic typology of business models (Figure 5.1), there has been identified a lack of a well-functioning collaborative relationship between the OEMs/battery collectors and the battery repurposers. An opportunity for future research is to conduct longitudinal action research with actors in the Norwegian market, exploring how changes to their business model would alter their value creation.

BIBLIOGRAPHY

Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. *Journal of management*, *43*(1), 39–58.

Ahuja, J., Dawson, L., & Lee, R. (2020). A circular economy for electric vehicle batteries: driving the change. *Journal of Property, Planning and Environmental Law*.

Albertsen, L., Richter, J. L., Peck, P., Dalhammar, C., & Plepys, A. (2021). Circular business models for electric vehicle lithium-ion batteries: An analysis of current practices of vehicle manufacturers and policies in the EU. *Resources, Conservation and Recycling*, *172*, 105658. https://doi.org/10.1016/J.RESCONREC.2021.105658

Armstrong, M. (2010). *Armstrong's handbook of reward management practice: Improving performance through reward*. Kogan Page Publishers.

Austefjord, B., & Opsahl, E. (2020). *Application of lean in high variety and low volume manufacturing (Master Thesis)*. University of Agder. https://hdl.handle.net/11250/2679949

Babbie, E. R. (2010). *The practice of social research* (12th ed.). Wadsworth Cengage Learning.

Beer, S., Gomez, T., Dallinger, D., Momber, I., Marnay, C., Stadler, M., & Lai, J. (2012). An Economic Analysis of Used Electric Vehicle Batteries Integrated Into Commercial Building Microgrids. *IEEE Transactions on Smart Grid*, *3*(1), 517–525. https://doi.org/10.1109/TSG.2011.2163091

Bibra, E. M., Connelly, E., Gorner, M., Lowans, C., Paoli, L., Tattini, J., & Teter, J. (2021). Global EV Outlook 2021: Accelerating Ambitions Despite the Pandemic.

Bjønnes, W. S., Grønningsæter, M. S., & Skibstad, K. Ø. (2020). *Electric vehicle battery for reuse*. University of Agder.

Bocken, N. M. P., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Journal of Industrial and Production Engineering Product design and business model strategies for a circular economy Product design and business model strategies for a circular economy. https://doi.org/10.1080/21681015.2016.1172124

Bräuer, S. (2016). *They Not Only Live Once – Towards Product-Service Systems for Repurposed Electric Vehicle Batteries*.

Bräuer, S., Monhof, M., Klör, B., Plenter, F., Beverungen, D., & Siemen, C. (2016). Residential Energy Storage from Repurposed Electric Vehicle Batteries: Market Overview and Development of a Service-Centered Business Model. *2016 IEEE 18th Conference on Business Informatics (CBI)*, 143–152. https://doi.org/10.1109/CBI.2016.24

Busch, T. (2013). *Akademisk skriving for bachelor- og masterstudenter [Academic writing for bachelor's and master's students]*. Fagbokforl.

Casadesus-Masanell, R., & Ricart, J. E. (2010). From Strategy to Business Models and onto Tactics. *Long Range Planning*, *43*(2), 195–215. https://doi.org/https://doi.org/10.1016/j.lrp.2010.01.004

Corbin, J., & Strauss, A. (2008). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (3rd ed.). SAGE Publications, Inc. https://doi.org/10.4135/9781452230153

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage publications. http://155.0.32.9:8080/jspui/bitstream/123456789/1091/1/Qualitative%2C%20Quantitative%2C%20and%20Mixed%20Methods%20Approaches%20%28%20PDFDrive%20%29-1.pdf

Del Busso, L., & Brottveit, G. (2018). *Vitenskapsteori og kvalitative forskningsmetoder : om å arbeide forskningsrelatert [Theory of science and qualitative research methods: about working research-related]*. Gyldendal akademisk.

Energy Agency, I. (2021). *Global EV Outlook 2021 Accelerating ambitions despite the pandemic* (tech. rep.). www.iea.org/t&c/

Engel, H., Hertzke, P., & Siccardo, G. (2019). *Second-life EV batteries: The newest value pool in energy storage* (tech. rep.). McKinsey & Company.

European Commission. (n.d.). CE marking. https://ec.europa.eu/growth/single-market/ce-marking_en

European Commission. (2006). Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC. http://data.europa.eu/eli/dir/2006/66/oj

European Commission. (2018). Consolidated text: Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC. http://data.europa.eu/eli/dir/2006/66/2018-07-04

European Commission. (2020). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020PC0798&from=EN

European Commission, Directorate-General for Internal Market Industry Entrepreneurship and SMEs, Bobba, S., Claudiu, P., Huygens, D., Alves Dias, P., Gawlik, B., Tzimas, E., Wittmer, D., Nuss, P., Grohol, M., Saveyn, H., Buraoui, F., Orveillon, G., Hámor, T., Slavko, S., Mathieux, F., Gislev, M., Torres De Matos, C., … Garbarino, E. (2018). *Report on critical raw materials and the circular economy*. Publications Office. https://doi.org/doi.org/10.2873/167813

Faessler, B. (2021). Stationary, second use battery energy storage systems and their applications: A research review. *Energies*, *14*(8). https://doi.org/10.3390/en14082335

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Hannan, M. A., Hoque, M. M., Hussain, A., Yusof, Y., & Ker, P. J. (2018). State-of-the-art and energy management system of lithium-ion batteries in electric vehicle applications: Issues and recommendations. *Ieee Access*, *6*, 19362–19378.

Hellström, M., & Wrålsen, B. (2020). *Modeling Business Ecosystems for spent Lithium-ion batteries*, University of Agder.

Hemmati, R. (2018). Optimal design and operation of energy storage systems and generators in the network installed with wind turbines considering practical characteristics of storage units as design variable. *Journal of Cleaner Production*, *185*, 680–693.

Hossain, E., Faruque, H. M. R., Sunny, M., Haque, S., Mohammad, N., & Nawar, N. (2020). A comprehensive review on energy storage systems: Types, comparison, current scenario, applications, barriers, and potential solutions, policies, and future prospects. *Energies*, *13*(14), 3651.

Hossain, E., Murtaugh, D., Mody, J., Faruque, H. M. R., Sunny, M. S. H., & Mohammad, N. (2019). A comprehensive review on second-life batteries: Current state, manufacturing considerations, applications, impacts, barriers & potential solutions, business strategies, and policies. *Ieee Access*, *7*, 73215–73252.

Hu, Y., Cheng, H., & Tao, S. (2017). Retired Electric Vehicle (EV) Batteries: Integrated Waste Management and Research Needs. *Environmental Science and Technology*, *51*(19), 10927–10929. https://doi.org/10.1021/ACS.EST.7B04207

Hua, Y., Liu, X., Zhou, S., Huang, Y., Ling, H., & Yang, S. (2021). Toward sustainable reuse of retired lithium-ion batteries from electric vehicles. *Resources, Conservation and Recycling*, *168*, 105249.

Hua, Y., Zhou, S., Huang, Y., Liu, X., Ling, H., Zhou, X., Zhang, C., & Yang, S. (2020). Sustainable value chain of retired lithium-ion batteries for electric vehicles. *Journal of Power Sources*, *478*, 228753. https://doi.org/10.1016/j.jpowsour.2020.228753

Idjis, H., & da Costa, P. (2017). Is Electric Vehicles Battery Recovery a Source of Cost or Profit? *The automobile revolution* (pp. 117–134). Springer International Publishing. https://doi.org/10.1007/978-3-319-45838-0{_}8

Ingeborgrud, L., & Ryghaug, M. (2019). The role of practical, cognitive and symbolic factors in the successful implementation of battery electric vehicles in Norway. *Transportation Research Part A: Policy and Practice*, *130*, 507–516.

Jiao, N. (2017). *Business Models for Second-life Electric Vehicle Battery Systems* (Doctoral dissertation). University of Cambridge. https://doi.org/10.17863/CAM.25955

Jiao, N., & Evans, S. (2016). Business Models for Sustainability: The Case of Second-life Electric Vehicle Batteries. *Procedia CIRP*, *40*, 250–255. https://doi.org/10.1016/j.procir.2016.01.114

Jiao, N., & Evans, S. (2018). Business Models for Repurposing a Second-Life for Retired Electric Vehicle Batteries. *Green energy and technology* (pp. 323–344). Springer, Cham. https://doi.org/10.1007/978-3-319-69950-9{_}13

Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing your business model. *Harvard business review*, *86*(12), 50–129.

Kalair, A., Abas, N., Saleem, M. S., Kalair, A. R., & Khan, N. (2021). Role of energy storage systems in energy transition from fossil fuels to renewables. *Energy Storage*, *3*(1), e135.

Klör, B., Beverungen, D., Bräuer, S., Plenter, F., & Monhof, M. (2015). A Market for Trading Used Electric Vehicle Batteries - Theoretical Foundations and Information Systems. *ECIS 2015 Completed Research Papers*. https://doi.org/10.18151/7217392

Klumpp, M. (2018). How to achieve supply chain sustainability efficiently? Taming the triple bottom line split business cycle. *Sustainability*, *10*(2), 397.

Kvale, S., Brinkmann, S., Anderssen, T. M., & Rygge, J. (2009). *Det kvalitative forskningsintervju [InterView: Learning the Craft of Qualitative Research Interviewing]* (2nd ed.). Gyldendal akademisk.

Lieberman, E. S. (2005). Nested Analysis as a Mixed-Method Strategy for Comparative Research. *American Political Science Review*, *99*(3), 435–452. https://doi.org/10.1017/S0003055405051762

Lih, W.-C., Yen, J.-H., Shieh, F.-H., & Liao, Y.-M. (2012). Second Use of Retired Lithium-ion Battery Packs from Electric Vehicles: Technological Challenges, Cost Analysis and Optimal Business Model. *2012 International Symposium on Computer, Consumer and Control*, 381–384. https://doi.org/10.1109/IS3C.2012.103

Merchant, K. A., & Van der Stede, W. A. (2007). *Management control systems: performance measurement, evaluation and incentives*. Pearson education.

Miao, Y., Hynan, P., Von Jouanne, A., & Yokochi, A. (2019). Current Li-ion battery technologies in electric vehicles and opportunities for advancements. *Energies*, *12*(6), 1074.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications, Inc.

Mir Mohammadi Kooshknow, S. A. R., den Exter, R., & Ruzzenenti, F. (2020). An Exploratory Agent-Based Modeling Analysis Approach to Test Business Models for Electricity Storage. *Energies*, *13*(7), 1617. https://doi.org/10.3390/en13071617

Montoya-Bedoya, S., Sabogal-Moncada, L. A., Garcia-Tamayo, E., & Martínez-Tejada, H. V. (2020). A Circular Economy of Electrochemical Energy Storage Systems: Critical Review of SOH/RUL Estimation Methods for Second-Life Batteries. *Green Energy and Environment*, *10*.

Morris, M., Schindehutte, M., & Allen, J. (2005). The entrepreneur's business model: Toward a unified perspective. *Journal of Business Research*, *58*(6), 726–735. https://doi.org/10.1016/J.JBUSRES.2003.11.001

Morse, J. M. (1991). Approaches to Qualitative-Quantitative Methodological Triangulation. *Nursing Research*, *40*(2). https://journals.lww.com/nursingresearchonline/Fulltext/1991/03000/Approaches_to_Qualitative_Quantitative.14.aspx

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, *17*(1), 2–26. https://doi.org/10.1016/J.INFOANDORG.2006.11.001

Olsson, L., Fallahi, S., Schnurr, M., Diener, D., & van Loon, P. (2018). Circular business models for extended ev battery life. *Batteries*, *4*(4). https://doi.org/10.3390/batteries4040057

Or, T., Gourley, S. W., Kaliyappan, K., Yu, A., & Chen, Z. (2020). Recycling of mixed cathode lithium-ion batteries for electric vehicles: Current status and future outlook. https://doi.org/10.1002/cey2.29

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons Inc.

Pagliaro, M., & Meneguzzo, F. (2019). Lithium battery reusing and recycling: A circular economy insight. *Heliyon*, *5*(6), e01866.

Pavković, D., Sedić, A., & Guzović, Z. (2016). Oil drilling rig diesel power-plant fuel efficiency improvement potentials through rule-based generator scheduling and utilization of battery energy storage system. *Energy conversion and management*, *121*, 194–211.

Pereira, C. R., Christopher, M., & Da Silva, A. L. (2014). Achieving supply chain resilience: the role of procurement. *Supply Chain Management: an international journal*.

Reinhardt, R., Christodoulou, I., Gassó-Domingo, S., & Amante García, B. (2019). Towards sustainable business models for electric vehicle battery second use: A critical review. *Journal of Environmental Management*, *245*, 432–446. https://doi.org/10.1016/J.JENVMAN.2019.05.095

Richardson, J. (2008). The business model: an integrative framework for strategy execution. *Strategic Change*, *17*(5-6), 133–144. https://doi.org/10.1002/JSC.821

Richardson, J. E. (2005). The Business Model: An Integrative Framework for Strategy Execution. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.932998

Rubin, H. J., & Rubin, I. S. (1995). *Qualitative Interviewing: The Art of Hearing Data* (1st ed.). SAGE Publications, Inc.

Schneider, E. L., Kindlein, W., Souza, S., & Malfatti, C. F. (2009). Assessment and reuse of secondary batteries cells. *Journal of Power Sources*, *189*(2), 1264–1269. https://doi.org/https://doi.org/10.1016/j.jpowsour.2008.12.154

Song, R., & Potoglou, D. (2020). Are existing battery electric vehicles adoption studies able to inform policy? A review for policymakers. *Sustainability*, *12*(16), 6494.

Sorauren, I. F. (2000). Non-monetary Incentives: Do people work only for money? *Business Ethics Quarterly*, 925–944.

Stahel, W. R. (2016). Circular economy. *Nature*, *531*(7595), 435–438. https://doi.org/http://dx.doi.org/10.1038/531435a

Wang, Q., Jiang, B., Li, B., & Yan, Y. (2016). A critical review of thermal management models and solutions of lithium-ion batteries for the development of pure electric vehicles. *Renewable and Sustainable Energy Reviews*, *64*, 106–128.

Warner, J. T. (2015). *The handbook of lithium-ion battery pack design: chemistry, components, types and terminology*. Elsevier.

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. *ACM International Conference Proceeding Series*. https://doi.org/10.1145/2601248.2601268

Yang, J., Gu, F., & Guo, J. (2020). Environmental feasibility of secondary use of electric vehicle lithium-ion batteries in communication base stations. *Resources, Conservation and Recycling*, *156*, 104713.

Yang, Y., Bremner, S., Menictas, C., & Kay, M. (2018). Battery energy storage system size determination in renewable energy systems: A review. *Renewable and Sustainable Energy Reviews*, *91*, 109–125.

Zhao, Y., Pohl, O., Bhatt, A. I., Collis, G. E., Mahon, P. J., Rüther, T., & Hollenkamp, A. F. (2021). A Review on Battery Market Trends, Second-Life Reuse, and Recycling. https://doi.org/10.3390/suschem2010011

Zubi, G., Dufo-López, R., Carvalho, M., & Pasaoglu, G. (2018). The lithium-ion battery: State of the art and future perspectives. *Renewable and Sustainable Energy Reviews*, *89*, 292–308. https://doi.org/https://doi.org/10.1016/j.rser.2018.03.002

APPENDICES

A | QUESTIONNAIRE SHEET

IND590-G Master Thesis
Kielland, K. and Skibstad, K. – Spring 2022

UiA School of Business and Law

Questionnaire Sheet

Intervjuspørsmål

First-time interview with/*Førstegangsintervju med* **COMPANY X**
Attendee/*Deltakende*: NAME, POSITION
Date/*Dato*: DD.MM.YYYY HH:MM-HH:MM

Q1: What is the business idea of COMPANY X?
S1: Hva er forretningsideen bak COMPANY X?

Q2: How does COMPANY X reuse batteries?
S2: På hvilken måte gjenbruker COMPANY X batterier?

Q3: What business strategies are used, and how do their business strategies differentiate COMPANY X from its competitors?
S3: Hvilke forretningsstrategier benyttes, og hva differensierer COMPANY X fra sine konkurrenter (iht. forretningsstrategier)?

Talking points: Key strategic decisions, Important Stakeholders, Competitors, and Current business model (other possible models?).

Samtaleemner: Strategiske veivalg, Viktige aktører/involverte, Konkurrenter, og Nåværende forretningsmodell (andre potensielle modeller?).

Q4: Through what channels does the collection of batteries take place?
S4: Hvilke kanaler benyttes for innsamlingen av batterier?

Q5: What barriers have COMPANY X identified for reuse of batteries?
S5: Hvilke barrierer har COMPANY X identifisert når det kommer til gjenbruk av batterier?

Q6: Are there any incentives in the market that COMPANY X takes advantage of? In a perfect COMPANY X-world, which incentives would make COMPANY X's business thrive the most?
S6: Benytter COMPANY X seg av noen insentiver i markedet? I en perfekt COMPANY X-verden, hvilke insentiver ville COMPANY X tjent mest på?

Master

UiA University of Agder